EVEREST YOUTH ACADEMY

Physics

Physics Notes and Problems with Solutions

June, 2023
Ethiopia

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Chapter 1

Vectors and Scalars

1.1 Scalar & Vector Quantities

All quantities can be one of two types:

- A scalar
- A vector

Scalars

- Scalars are quantities that have only a magnitude
- For example, mass is a scalar since it is a quantity that has magnitude without a direction
- A quantity which is completely specified by a certain number associated with a suitable unit without any mention of direction in space is known as scalar.
- Examples of scalar are time, mass, length, volume, density, temperature, energy, distance, speed etc.
- The number describing the quantity of a particular scalar is known as its magnitude.
- The scalars are added subtracted, multiplied and divided by the usual arithmetical laws.

Vector

- Vectors have both magnitude and direction
- A quantity which is completely described only when both their magnitude and direction are specified is known as vector.
- Examples of vector are force, velocity, acceleration, displacement, torque, momentum, gravitational force, electric and magnetic intensities etc.
- A vector is represented by a Roman letter in bold face and its magnitude, by the same letter in italics. Thus V means vector and V is magnitude

1.2 Representation of vectors

The representation of vector is done by using the arrow. We know that an arrow contains a head and a tail. The head of the arrow denotes the direction of the vector. To denote vectors, arrows are marked above the representative symbols for them. Examples include $\vec{A}$

1.3 Adding and Subtracting Vectors

In Physics, vector quantities are quantities that have a magnitude and direction. It is important to understand how operations like addition and subtraction are carried out on vectors. The sum of two or more vectors is called the resultant. The resultant of two vectors can be found using either the parallelogram method or the triangle method .

1) **Parallelogram Law for Addition of Vectors**

- In parallelogram law, the two vectors start from the same initial point in two different directions.
- If the two vector $\vec{A}$ and $\vec{B}$ are given such that the angle between them is θ, in that case, the magnitude of the resultant vector $\vec{R}$ of the addition of vectors is stated by

$$|R| = \sqrt{|A|^2 + |B|^2 + 2|A||B|cos\theta} \tag{1.1}$$

- The magnitude of the resultant vector depends on the angle between vector $\vec{A}$ and $\vec{B}$.
- If $\vec{A}$ and $\vec{B}$ are in the same direction, the magnitude of the resultant vector will be given as follows, respectively.

$$|R| = |A| + |B| \tag{1.2}$$

- If $\vec{A}$ and $\vec{B}$ are in the opposite direction the magnitude of the resultant vector will be given as follows

$$|R| = |A| - |B| \tag{1.3}$$

- If $\vec{A}$ and $\vec{B}$ are perpendicular with each other, the magnitude of the resultant vector will be given as follows, respectively.

$$|R| = \sqrt{|A|^2 + |B|^2} \tag{1.4}$$

2) Triangle law

- Triangle law is for two vectors when the second vector deviates from the direction of the first vector. Note here that second vector starts after the first vector.

Difference between triangle law and triangle law of vector addition These both laws are the same. But there is a minor difference between them on the basis of theory, application, & usefulness. forexample:

Parallelogram Law:

- If two vectors, vector 'A' & vector 'B' are represented in magnitude & direction by the two adjacent sides of a parallelogram, then their sum, vector 'C' is represented by the diagonal of the parallelogram which is coinitial with the given vectors. .
- The parallelogram law asks to put the tails (end without the arrow) of the two vectors at the same point.

Triangle Law:

- Triangle Law: If two vectors are represented in magnitude & direction by the two sides of a triangle taken in the same order, then their sum is represented by the third side taken in the reverse order
- The triangle law asks to take the tail of the second vector and place it at the head of the first vector.

Multiple Choice Questions

1. Which of the following is a physical quantity that has a magnitude but no direction?

   A. Vector   B. Frame of reference   C. Resultant   D. Scalar   Answer: D

2. Identify the following quantities as scalar or vector: the mass of an object, the number

of leaves on a tree, and wind velocity.

A. Vector, scalar, scalar

B. Vector, scalar, vector

C. Scalar, scalar, vector

D. Scalar, vector, vector

Answer: C

3. When a vector is multiplied by a negative number, its direction changes by an angle of:
(A)0^0 (B)90^0 (C)180^0 (D)360^0 Answer: C

4. Unit vectors are used to specify:
(A) Magnitude of vector (B) Direction of vector (C) Magnitude as well as direction of vector (D) Unit of other vectors Answer: B

5. The magnitude of resultant of 3N and 4N force acting perpendicularly on a body is: (A) 1 N (B) 2 N (C) 7 N (D) 5 N Answer: D

6. The resultant of A + (-A) is called:
(A) Zero or null vector (B) Position vector (C) Free vector (D) Unit vector Answer: A

7. The addition of two or more vectors is called: (A) Null vector (B) Position vector (C) Resultant vector (D) Negative vector Answer: C

8. Five equal forces of 10 N are applied at a point. If the angle between them is equal, what is the resultant force?
A) 10N B) $20\sqrt{2}$ N C) 20 N D) 0 Answer: D

9. A boy walks uniformly along the sides of a rectangular park with dimensions 400 m×300 m, starting from one corner to the other corner diagonally opposite. Which of the following statements is false?
A) His displacement is 700 m
B) His displacement is 500 m

C) He has travelled a distance of 700 m

D) His velocity is not uniform throughout the walk

Answer: A

10. Identify the row that contains two scalars and one vector quantity.

A distance, acceleration, velocity

B speed, mass, acceleration

C distance, weight, force

D speed, weight, acceleration

E velocity, force, mass

Answer: B

11. Two vectors of magnitudes 25 and 15 are added together. The minimum magnitude of the resultant vector is

A) 25 B) 10 C) 40 D) 15

Answer: B

12. A race car circles a 1500 meter track 5 times. The total displacement of the race car is

A) 0m B) must know time to answer C) 1500m D) 7500m Answer: A

Chapter 2

Motion in a straight line

2.1 Physical Quantities and Their Classification

Motion: Motion means movement. The motion of an object is perceived when its position changes continuously with respect to some stationary object.

Distance: The distance travelled by an object is the length of actual path travelled by the object during the motion.

Displacement

The displacement of an object is the shortest distance travelled between the initial and final position of the object.

- When final position coincides with the initial position, displacement is 0 but distance is not equal to 0.
- Both, the distance and displacement are measure in meter or cm or km.
- Distance is a scalar quantity having only.
- Displacement is a vector quantity having both magnitude and direction.
- The distance traveled by an object in motion can never be zero or negative.
- The displacement can be positive, zero or negative.

Example:

Which of the following is true for displacement? (a) It cannot be zero. (b) Its magnitude is greater than the distance travelled by the object. Ans. (a) Not true. Displacement can become zero when the initial and final position of the object is the same.

2.2 VELOCITY-TIME GRAPH

The geometrical relationship between the velocity of an object and the time taken by the object is called the velocity-time graph. The velocity-time graph of an object can be drown by taking the time taken along the X-axis and the velocity along the Y-axis. The ratio of the velocity and the time taken will give the acceleration of the object. Therefore, the slope of the velocity-time graph gives the acceleration of the given object. That is, by using this graph one can find the acceleration of an object. The velocity-time graph under different conditions are shown below.

1) **When the body is moving with uniform velocity**

If the object moves at uniform velocity, the height of its velocity-time graph will not change with time. It will be a straight line parallel to the x-axis. We know that the product of velocity and time give displacement of an object moving with uniform velocity. The area enclosed by velocity-time graph and the time axis will be equal to the magnitude of the displacement.

2.3 EQUATIONS OF MOTION BY GRAPHICAL METHOD

When an object moves along a straight line with uniform acceleration, it is possible to relate its velocity, acceleration during motion and the distance covered by it in a certain time interval by a set of equations known as the equations of motion. There are three such equations. These are:

$$v = u + at \tag{2.1}$$

$$S = ut + \frac{1}{2}at \tag{2.2}$$

$$2aS = v^2 - u^2 \tag{2.3}$$

where u is the initial velocity of the object which moves with uniform acceleration a for time t, v is the final velocity, and s is the displacement travelled by the object in time t.

2.4 UNIFORM CIRCULAR MOTION

An athlete runs along the circumference of a circular path. This type of motion is known as circular motion. The movement of an object in a circular path is called circular motion. When an object moves in a circular path with a constant velocity, its motion is called uniform circular motion. In uniform circular motion, the magnitude of the velocity is constant at all points and the direction of the velocity changes continuously. We know that the circumference of a circle of radius r is given by $2\pi r$. If the athlete takes t seconds to go once around the circular path of radius r, the velocity v is given by

$$v = \frac{2\pi r}{t} \tag{2.4}$$

Example: 1. What is the nature of the distance-time graphs for uniform and non-uniform motion of an object?

Ans. The distance-time graph for uniform motion of an object is a straight line (as shown in the following figure).

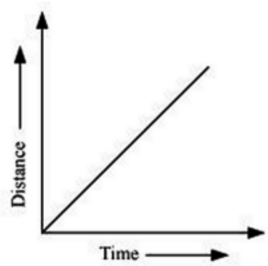


Fig. 2.1. Distance-time graph

The distance-time graph for non-uniform motion of an object is a curved line (as shown in the given figure). 2. What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis?

Ans. When an object is at rest, its distance-time graph is a straight line parallel to the time axis. A straight line parallel to the x-axis in a distance-time graph indicates that with a change in time, there is no change in the position of the object. Thus, the object is at rest.

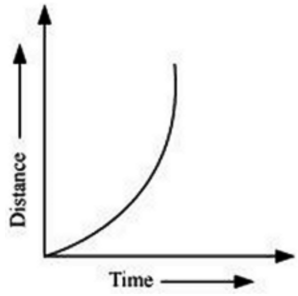


Fig. 2.2. Distance-time graph

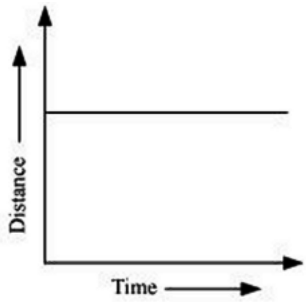


Fig. 2.3. Distance-time graph

3. What can you say about the motion of an object if its speed-time graph is a straight line parallel to the time axis?

Ans. Object is moving uniformly.A straight line parallel to the time axis in a speed-time graph indicates that with a change in time, there is no change in the speed of the object. This indicates the uniform motion of the object.

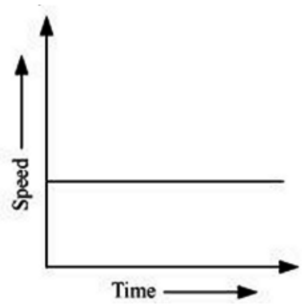


Fig. 2.4. speed-time graph

Multiple Choice Questions

1. The average speed of a moving object during a given interval of time is always:

   A. the magnitude of its average velocity over the interval

   B. the distance covered during the time interval divided by the time interval

   C. one-half its speed at the end of the interval

   D. its acceleration multiplied by the time interval

   E. one-half its acceleration multiplied by the time interval.

   ans: B

2. When is the average velocity of an object equal to the instantaneous velocity?

   A) always

   B) never

   C) only when the velocity is constant

   D) only when the velocity is increasing at a constant rate

   Answer: C

3. What must be your average speed in order to travel 350 km in 5.15 h?

   A) 66.0 km/h

   B) 67.0 km/h

   C) 68.0 km/h

   D) 69.0 km/h

   Answer: C

4. If you run a complete loop around an outdoor track (400 m), in 100 s, your average velocity is

   A) 0.25 m/s.

   B) 4.0 m/s.

   C) 40,000 m/s.

   D) zero.

   Answer: D

5. A particle moves along the x axis from x_i to x_f . Of the following values of the initial and final coordinates, which results in the displacement with the largest magnitude?

   A.x_i = 4 m, x_f = 6 m

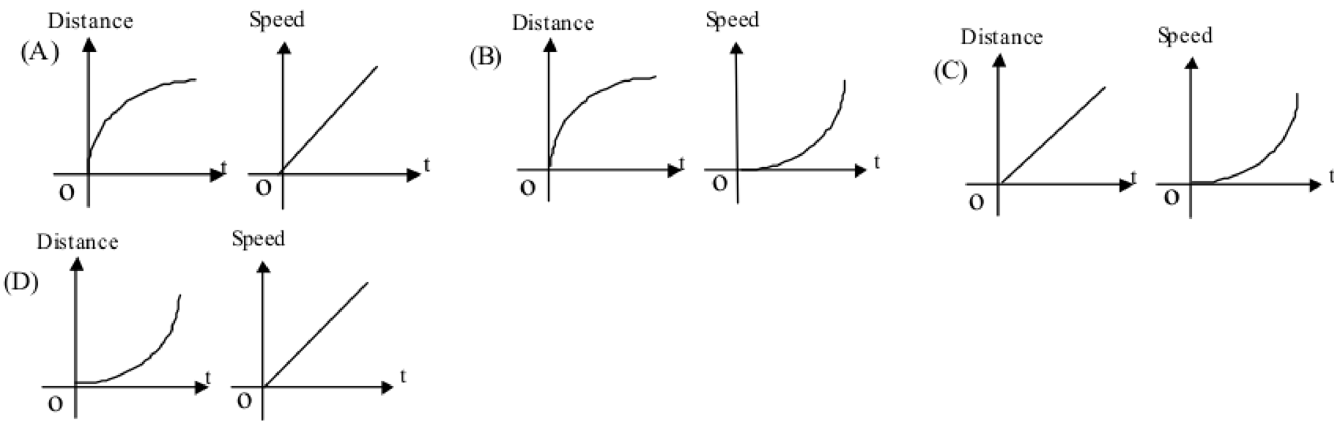
   B. x_i = -4 m, x_f = -8 m

   C. x_i = -4 m, x_f = 2 m

   D. x_i = 4 m, x_f = -2 m

   E. x_i = -4.

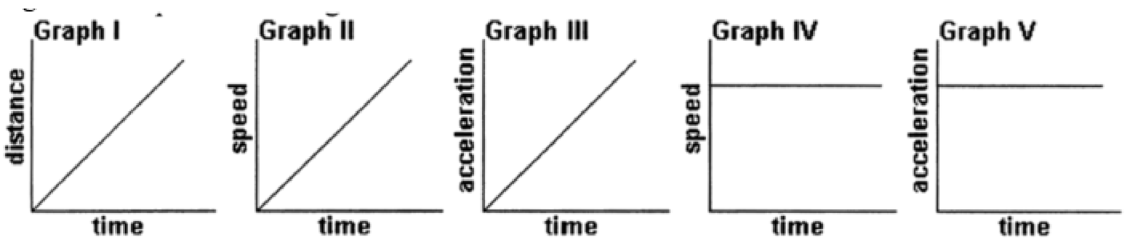
6. Which of the following pairs of graphs shows the distance traveled versus time and the speed versus time for an object uniformly accelerated from rest? object uniformly accelerated from rest?



7. A car travels east at constant velocity. The net force on the car is:——

   A. east B. west C. up D. down E. zero

8. Which of the following graphs could correctly represent the motion of an object moving with a constant speed in a straight line? A. Graph I only B. Graphs II and V only C.



   Graph II only D. Graphs I and IV only

9. A train is traveling on a straight track at a constant speed. In 80 seconds it covers a distance of 2400 meters. What is the speed of the train?

   (a) 30 m/s (b) 40 m/s (c) 60 m/s (d) 100 m/s

10. A car is traveling on a straight highway at a speed of 90 km/h. How far does the car travel in 15 minutes?

    (a) 50 km (b) 30 km (c) 22.5 km (d) 12.5 km

11. . A car accelerates from rest to a speed of 20 m/s in 10 seconds. What is the acceleration of the car during this time interval?

    (a) 1m/s^2 (b) 2m/s^2 (c) 0.5m/s^2 (d) 5m/s2

12. A man walks 7 km in 2 hours and 2 km in 1 hour in the same direction. What is the man's average velocity for the whole journey?

    (a) 3 km/h (c) 2 km/h

    (b) 2 km/h in the same direction (d) 3 km/h in the same direction

13. What are three ways an object can accelerate?

    (a) By speeding up, maintaining constant velocity, or changing direction

    (b) By speeding up, slowing down, or changing direction

    (c) By maintaining constant velocity, slowing down, or changing direction

    (d) By speeding up, slowing down, or maintaining constant velocity

14. The area under a velocity-time graph represents:

    (a) acceleration (b) displacement (c) speed (d) change in velocity

15. . Suppose that an object travels from one point in space to another. Make a comparison between the displacement and the distance traveled.

    (a) The displacement is either greater than or equal to the distance traveled.

    (b) The displacement is always equal to the distance traveled.

    (c) The displacement is either less than or equal to the distance traveled.

    (d) The displacement can be either greater than, smaller than, or equal to the distance

16. Why should you specify a reference frame when describing motion?

    (a) description of motion depends on the reference frame

    (b) motion appears the same in all reference frames

    (c) reference frames affect the motion of an object

    (d) you can see motion better from certain reference frames

Chapter 3

FORCE AND LAWS OF MOTION

3.1 Force

- A force is anything that can cause a change to objects. Forces can:
- change the shape of an object
- move or stop an object
- change the direction of a moving object.
- A force can be classified as either a contact force or a non-contact force.
- A contact force must touch or be in contact with an object to cause a change. Examples of contact forces are:
- the force that is used to push or pull things, like on a door to open or close it
- the force that a sculptor uses to turn clay into a pot
- the force of the wind to turn a windmill A non-contact force does not have to touch an object to cause a change. Examples of non- contact forces are:
- the force due to gravity, like the Earth pulling the Moon towards itself
- the force due to electricity, like a proton and an electron attracting each other
- the force due to magnetism, like a magnet pulling a paper clip towards itself.

The unit of force is the newton (symbol N). This unit is named after Sir Isaac Newton who first defined force. Force is a vector quantity and has a magnitude and a direction.

EFFECT OF FORCE:

- Force can make a stationary body in motion. For example a football can be set to move by kicking it, i.e. by applying a force.
- Force can stop a moving body – For example by applying brakes, a running cycle or a running vehicle can be stopped.
- Force can change the direction of a moving object. For example; By applying force, i.e. by moving handle the direction of a running bicycle can be changed. Similarly by moving steering the direction of a running vehicle is changed.
- Force can change the speed of a moving body – By accelerating, the speed of a running vehicle can be increased or by applying brakes the speed of a running vehicle can be decreased.
- Force can change the shape and size of an object. For example -– By hammering, a block of metal can be turned into a thin sheet. By hammering a stone can be broken into pieces.

Forces are can also divided into two types:

1. Balanced Forces
2. Unbalanced Forces

1) BALANCED FORCES

- If the resultant of applied forces is equal to zero, it is called balanced forces.
- Example : - In the tug of war if both the teams apply similar magnitude of forces in opposite directions, rope does not move in either side. This happens because of balanced forces in which resultant of applied forces become zero.
- Balanced forces do not cause any change of state of an object.
- Balanced forces are equal in magnitude and opposite in direction.
- Balanced forces can change the shape and size of an object.
- For example - When forces are applied from both sides over a balloon, the size and shape of balloon is changed.

2) UNBALANCED FORCES

If the resultant of applied forces are greater than zero the forces are called unbalanced forces. An object in rest can be moved because of applying balanced forces. Unbalanced forces can do the following:

- Move a stationary object.
- Increase the speed of a moving object.
- Decrease the speed of a moving object.
- Stop a moving object.
- Change the shape and size of an object.

3.2 Laws of Motion

3.2 .1 NEWTON'S LAWS OF MOTION:

- Newton's First Law of Motion : Any object remains in the state of rest or in uniform motion along a straight line, until it is compelled to change the state by applying external force.
- Newton's Second Law of Motion : The rate of change of momentum is directly proportional to the force applied in the direction of force.
- Newton's Third Law of Motion - There is an equal and opposite reaction for evrey action

3.2 .2 Newton's first law of motion

- Any object remains in the state of rest or in uniform motion along a straight line, until it is compelled to change the state by applying external force.
- Explanation: If any object is in the state of rest, then it will remain in rest untill a exernal force is applied to change its state. Similarly an object will remain in motion untill any external force is applied over it to change its state. This means all objects resist to in changing their state. The state of any object can be changed by applying external forces only
- Newton's first law of motion: An object at rest stays at rest and an object in motion

stays in motion with the same speed in the same direction **unless acted upon by an unbalanced force.**

- Newton's first law of motion, sometimes called the Law of inertia.

3.2 .3 Newton's 2nd second law

- Newton's 2nd second law is more notably named as the law of acceleration.
- Newton's 2nd law states that the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the object's mass.
- In fact, the acceleration of a body is directly proportional to the net force acting on it

We have developed Newton's second law and presented it as a vector equation as given follow. This vector equation can be written as three component equations:

$$\sum \vec{F} = m\vec{a} \tag{3.1}$$

3.2 .4 Newton's third laws of Motion

- Newton's third law is the law of Interaction or the law of action and reaction.
- All forces occur in pairs, and these two forces are equal in magnitude and opposite in direction.
- For every action, there is an equal and opposite reaction.

3.3 Exercise

1. Acceleration is always in the direction:

   A. of the displacement

   B. of the initial velocity

   C. of the final velocity

   D. of the net force

E. opposite to the frictional force

ans: D

2. The inertia of a body tends to cause the body to: A. speed up

   B. slow down

   C. resist any change in its motion

   D. fall toward Earth

   E. decelerate due to friction

   ans: C

3. When a certain force is applied to the standard kilogram its acceleration is 5.0 m/s . When the same force is applied to another object its acceleration is one-fifth as much. The mass of the object is:

   A. 0.2 kg B. 0.5 kg C. 1.0 kg D. 5.0 kg E. 10 kg ans: D

4. Mass differs from weight in that:

   A. all objects have weight but some lack mass

   B. weight is a force and mass is not

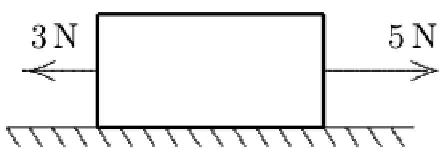
   C. the mass of an object is always more than its weight

   D. mass can be expressed only in the metric system

   E. there is no difference

   ans: B

5. The block shown in moves with constant velocity on a horizontal surface. Two of the forces on it are shown. A frictional force exerted by the surface is the only other horizontal force on the block. The frictional force is:

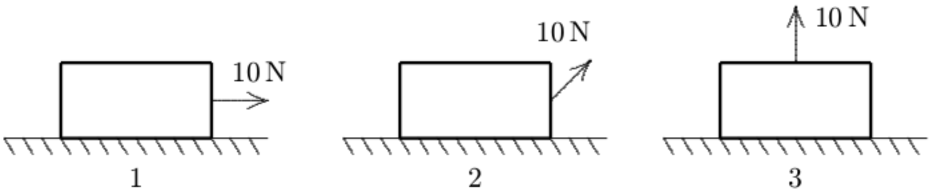


A) 0 B) 2 N, leftward C) 2 N, rightward D) slightly more than 2 N, leftward

E) slightly less than 2 N, leftward

ans: B

6. A crate rests on a horizontal surface and a woman pulls on it with a 10-N force. Rank the situations shown below according to the magnitude of the normal force exerted by the surface on the crate, least to greatest.



A) 1, 2, 3 B) 2, 1, 3 C) 2, 3, 1 D)1, 3, 2 E) 3, 2, 1 ans: E

7. A 6-kg object is moving south. A net force of 12 N north on it results in the object having an acceleration of:

A. 2 m/s^2 , north

B. 2m/s^2 , south

C. 6 m/s^2 , north

D. 18m/s^2 , north

E. 18 m/s^2 , south

ans: A

8. A car travels east at constant velocity. The net force on the car is:

A. east B. west C. up D. down E. zero ans: E

9. An object rests on a horizontal frictionless surface. A horizontal force of magnitude F is applied. This force produces an acceleration:

A. only if F is larger than the weight of the object

B. only while the object suddenly changes from rest to motion

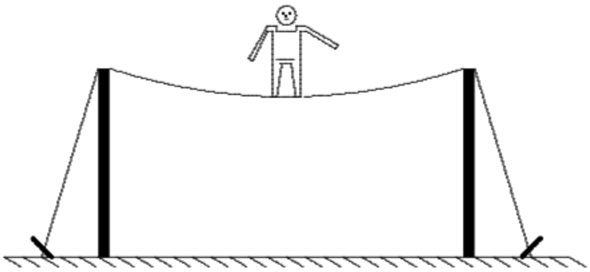
C. always

D. only if the inertia of the object decreases

E. only if F is increasing

ans: C

10. A circus performer of weight W is walking along a “high wire” as shown. The tension in the wire:



A) is approximately W

B) is approximately W/2

C) is much less than W

D) is much more than W

E) depends on whether he stands on one foot or two feet

ans: D

11. The “reaction” force does not cancel the “action” force because:

A. the action force is greater than the reaction force

B. they are on different bodies

C. they are in the same direction

D. the reaction force exists only after the action force is removed

E. the reaction force is greater than the action force

ans: B

12. A book rests on a table, exerting a downward force on the table. The reaction to this force is:

A. the force of Earth on the book

B. the force of the table on the book

C. the force of Earth on the table

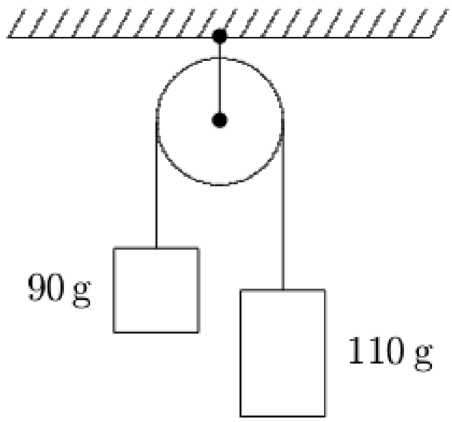
D. the force of the book on Earth

E. the inertia of the book

ans: B

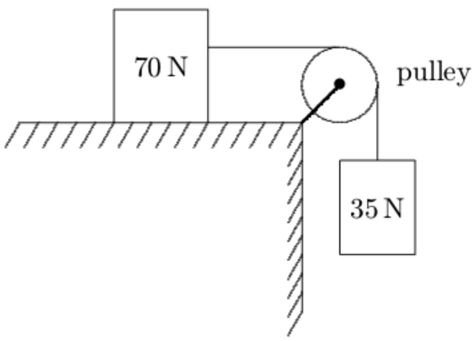
13. Two blocks are connected by a string and pulley as shown. Assuming that the string and pulley are massless, the magnitude of the acceleration of each block is:

A) 0.049 m/s^2 B) 0.020 m/s^2 C) 0.0098 m/s^2 D) 0.54 m/s^2 E) 0.98 m/s^2



ans: E

14. A 70-N block and a 35-N block are connected by a string as shown. If the pulley is massless and the surface is frictionless, the magnitude of the acceleration of the 35-N block is:



A) 1.6$m/s^2 m/s^2$

B) 3.3m/s^2

C) 4.9 m/sm/s^2

D) 6.7 m/s2m/s^2

E) 9.8 m/sm/s^2

ans: B

Chapter 4

WORK AND ENERGY

4.1 WORK

Work (W) is said to be done, when a force (F) acts on the body and point of application of the force is displaced (s) in the direction of force.

$$Work = Force \times displacement = F \times S \tag{4.1}$$

- If the body is displaced in the same direction of force, work is done by a force
- If the displacement is against a force, the work is done against the force.
- If the displacement is perpendicular to the direction of the force, work done is zero.

4.1 .1 ENERGY

- The energy of the body is defined as its capacity to do work.
- Energy is measured in terms of work. Unit of energy is also joule. One joule of energy is required to do one joule of work.
- Some important forms of energy are mechanical energy, chemical energy, light energy, heat energy, electrical energy, nuclear energy and sound energy.

MECHANICAL ENERGY

- The energy used to displace a body or to change the position of the body or to deform the body is known as mechanical energy.

- Mechanical energy is of two types i) Kinetic energy ii) Potential energy

KINETIC ENERGY

- Energy possessed by an object due to its motion is called kinetic energy.
- Kinetic energy of an object increases with its speed.
- Kinetic energy of an object moving with a velocity is equal to the work done on it to make it acquire that velocity.
- Kinetic Energy of a moving object is defined as half the product of the mass of the object square of the speed of the object.

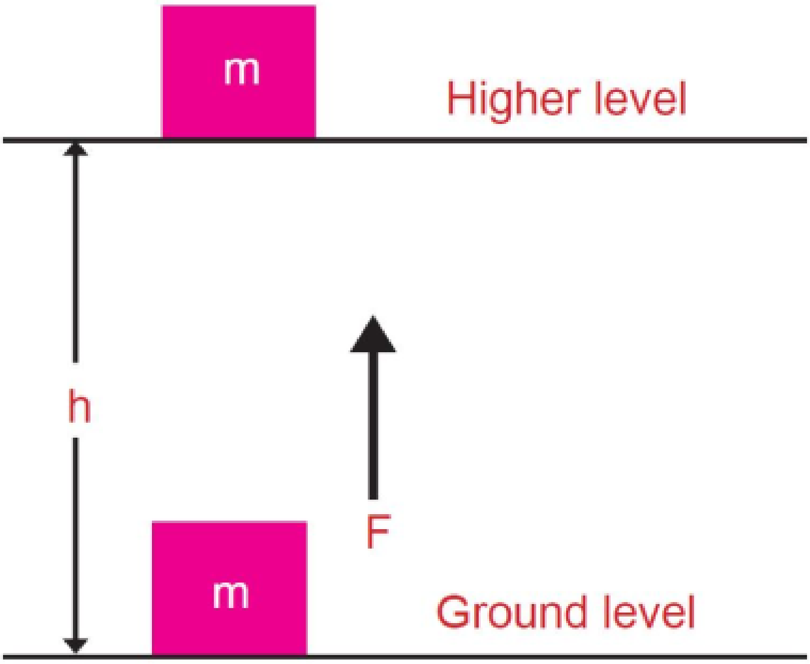
$$KE = \frac{1}{2}mv^2 \tag{4.2}$$

POTENTIAL ENERGY

- The energy possessed by a body by virtue of its position or due to state of strain, is called potential energy.
- The work done to lift a body above the ground level gives the potential energy of the body. Eg. weight lifting.
- Consider an object of mass m. It is raised through a height h from the ground. Force is needed to do this. The downward force acting on the body due to gravity = mg. The work has to be done to lift the body through a height h against the force of gravity as shown in above figure

$$w = mgh \tag{4.3}$$

- The potential energy of an object at a height depends on the ground level or the zero level you choose. An object in a given position can have a certain potential energy with respect to one level and a different value of potential energy with respect to another level.



4.1 .2 POWER

- Power is defined as the rate of doing work or the rate of transfer of energy.
- Power is the rate of doing work or the rate of transfer of energy.
- If an agent does a work W in time t, then power is given by:

$$p = \frac{work}{time} = \frac{energy}{time} \tag{4.4}$$

- The unit of power is watt having the symbol W. 1 watt is the power of an agent, which does work at the rate of 1 joule per second.
- Power is 1 W when the rate of consumption of energy is 1 J/s.

4.1 .3 Work- Energy theorem

We know from the study of Newton's laws in Dynamics: Force and Newton's Laws of Motion that net force causes acceleration. We will see in this section that work done by the net force gives a system energy of motion, and in the process we will also find an expression for the energy of motion. The principle of work and kinetic energy (also known as the work-energy theorem) states that the work done by the sum of all forces acting on a particle equals the change in the kinetic energy of the particle. The work W done by the net force on a particle equals the change in the particle's kinetic energy KE:

$$W_{net} = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \tag{4.5}$$

where v_i and v_f are the speeds of the particle before and after the application of force, and m is the particle's mass. The work-kinetic energy theorem indicates that the speed of a system increases if the net work done on it is positive. The speed decreases if the net work is negative.

The sum of kinetic and potential energies is known as Mechanical energy. Thus,we can express mechanical energy as:

Mechanical Energy = Kinetic Energy + Potential Energy

Mechanical Energy is the sum of the potential energy and kinetic energy in a system.

4.1 .4 Conservation of energy

The law of conservation of energy states that energy can neither be created nor destroyed - only converted from one form of energy to another. This means that a system always has the same amount of energy, unless it's added from the outside. The law of conservation of energy states that the total energy of an isolated system remains constant, it is said to be conserved over time. This law means that energy can neither be created nor destroyed; rather, it can only be transformed from one form to another. Energy in a system may take on various forms (e.g. kinetic, potential, heat, light). The law of conservation of energy states that energy may neither be created nor destroyed. Therefore the sum of all the energies in the system is a constant.

Multiple Choice Questions

1. A 1-kg block is lifted vertically 1 m by a boy. The work done by the boy is about: A. 100J B. 1 J C. 10 J D. 0.1 J E. zero ans: C

2. An object moves in a circle at constant speed. The work done by the centripetal force

is zero because:

A. the displacement for each revolution is zero

B. the average force for each revolution is zero

C. there is no friction

D. the magnitude of the acceleration is zero

E. the centripetal force is perpendicular to the velocity

ans: E

3. The work done by gravity during the descent of a projectile:

A. is positive

B. is negative

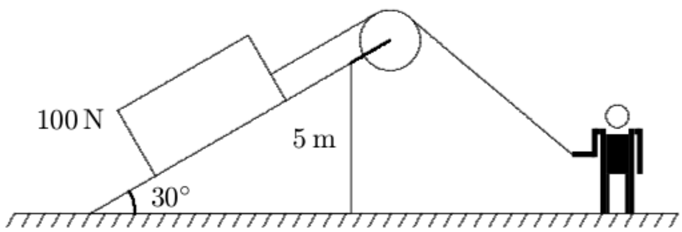
C. is zero

D. depends for its sign on the direction of the y axis

E. depends for its sign on the direction of both the x and y axes

ans: A

4. A man pulls a 100-N crate up a frictionless 30° slope 5 m high, as shown. Assuming that the crate moves at constant speed, the work done by the man is:



A) -500 J B) -250 J C) 0 D) 250 J E) 500 J ans: E

5. A man pushes an 80-N crate a distance of 5.0 m upward along a frictionless slope that makes an angle of 30° with the horizontal. His force is parallel to the slope. If the speed of the crate decreases at a rate of 1.5 m/s2 , then the work done by the man is:

A. -200 J B. 61 J C. 140 J D. 200 J E. 260 J ans: C

6. A man pulls a sled along a rough horizontal surface by applying a constant force F at an angle θ above the horizontal. In pulling the sled a horizontal distance d, the work done by the man is:

   A. F d   B. F d cosθ C. F d sinθ D. F d/ cosθ E. F d/ sinθ ans: B

7. A man wishes to pull a crate 15 m across a rough floor by exerting a force of 100 N. The coefficient of kinetic friction is 0.25. For the man to do the least work, the angle between the force and the horizontal should be:

   A. 0   B. 14°   C. 43°   D. 66°   E. 76°   ans: A

8. A particle moves 5 m in the positive x direction while being acted upon by a constant force $\vec{F}$ = (4 N)i + (2 N)j - (4 N)k. The work done on the particle by this force is:

   A. 20 J   B. 10 J   C. -20 J   D. 30 J   E. is impossible to calculate without knowing other forces   ans: A

9. Two trailers, X with mass 500 kg and Y with mass 2000 kg, are being pulled at the same speed. The ratio of the kinetic energy of Y to that of X is:

   A. 1:1   B. 2:1   C. 4:1   D. 9:1   E. 1500:1   ans: C

10. A 8000-N car is traveling at 12 m/s along a horizontal road when the brakes are applied. The car skids to a stop in 4.0 s. How much kinetic energy does the car lose in this time?

    A. 4.8×10^4 J   B. 5.9×10^4 J   C. 1.2×10^5J   D. 5.8×10^5 J   E. 4.8×10^6 ans: B

11. The amount of work required to stop a moving object is equal to:

    A. the velocity of the object

    B. the kinetic energy of the object

    C. the mass of the object times its acceleration

    D. the mass of the object times its velocity

    E. the square of the velocity of the object

    ans: B

12. A 5.0-kg cart is moving horizontally at 6.0 m/s. In order to change its speed to 10.0

m/s, the net work done on the cart must be:

A. 40 J B. 90 J C. 160 J D. 400 J E. 550 J ans: C

13. At time t = 0 a 2-kg particle has a velocity of (4 m/s)i - (3 m/s) j. At t = 3 s its velocity is (2 m/s)i + (3 m/s) j. During this time the work done on it was:

A. 4 J B. -4 J C. -12 Jv D. -40 J E. (4 J)i + (36 J)j ans: C

Chapter 5

Wave motion and sound

5.1 Wave motion and sound

- **Waves** is a disturbance that carries energy from place to place.
- A wave is a transfer of ENERGY from one point to another without the transfer of material between the points
- WAVES “MOVE” ENERGY, NOT MATTER
- Medium
  - material through which a wave transfers energy
  - it may be solid, liquid, gas, or combination
  - electromagnetic waves don’t need a medium (e.g. visible light)
- Some waves do not need matter (called a “medium”) to be able to move (for example, through space). These are called electromagnetic waves (or EM waves).
- Some waves MUST have a medium in order to move. These are called mechanical waves
- Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation.
- Sound waves are pressure waves caused by objects which are vibrating. Sound waves need a medium through which to travel.
- A medium is the substance or material through which a pulse or a wave moves.
- MECHANICAL WAVES-move through a media (solid, liquid, or gas).
- Two Types waves : Longitudinal Transverse.

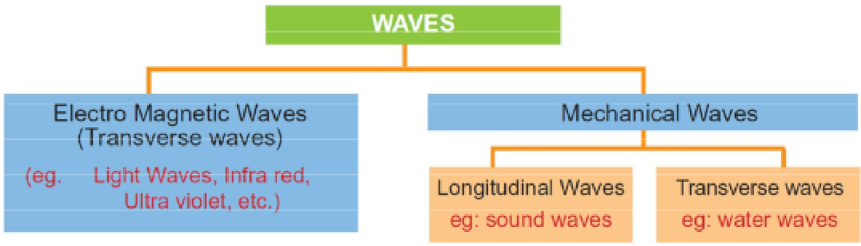


Fig. 5.1. Types of waves

5.1 .1 A longitudinal wave

- A longitudinal wave is a wave where the particles in the medium move parallel to the direction of propagation of the wave.
- "If the particles of a medium vibrate in a direction, parallel to or along the direction of propagation of wave, it is called longitudinal wave"
- Sound waves are pressure waves caused by objects which are vibrating. Sound waves need a medium through which to travel.
- Examples of longitudinal waves include:sound waves ultrasound waves seismic P-waves

Parts of longitudinal waves:

- **Compression**: where the particles are close together
- **Rarefaction:** where the particles are spread apart

Sound Waves

- Longitudinal wave created by a vibrating object
- Can only be transmitted in a medium
- Cannot exist in a vacuum

5.1 .2 Transverse Waves

- If the particles of the medium vibrate in a direction, perpendicular to the direction of propagation, the wave is called transverse wave.
- Example: water waves, vibrations of stretched string.
- Transverse waves propagate in a medium in the form of crests and troughs.

Parts of transverse waves:

- **Crest** : The maximum displacement along the upward direction.
- **Trough**: The maximum displacement along the downward direction.
- **Amplitude:** maximum displacement, or height of a wave
- **Wavelength:** distance between to successive points on a wave (ex. crest to crest)
- **Period:** time it takes a wave to make a complete cycle

5.2 Wave characteristics

- **Amplitude:** the height of the wave, measured in meters.
- **Wavelength (λ)**: the distance between adjacent crests, measured in meters.
- **Period:** the time it takes for one complete wave to pass a given point, measured in seconds.

$$T = \frac{1}{f} \tag{5.1}$$

- **Frequency:** the number of complete waves that pass a point in one second, measured in inverse seconds, or Hertz (Hz).

$$f = \frac{1}{T} \tag{5.2}$$

- **Speed:** the horizontal speed of a point on a wave as it propagates, measured in meters / second.

$$v = \lambda f \tag{5.3}$$

Chapter 6

Motion in 2D

6.1 Projectile Motion

- Projectile motion is the motion of an object thrown (projected) into the air when, after the initial force that launches the object, air resistance is negligible and the only other force that object experiences is the force of gravity.
- Projectile motion is one type of two-dimensional motion under constant acceleration, where $a_x = 0$ and $a_y = -g$.
- The object is called a projectile, and its path is called its trajectory.
- Air resistance is a frictional force that slows its motion and can significantly alter the trajectory of the motion.
- The most important experimental fact about projectile motion in two dimensions is that the horizontal and vertical motions are completely independent of each other.

About Initial Velocity

- The initial velocity can be expressed as x components and y components:

$$v_{ix} = v_i \cdot cos\theta \tag{6.1}$$

$$v_{iy} = v_i \cdot sin\theta \tag{6.2}$$

About Time of Flight

- The time of flight of a projectile motion is the time from when the object is projected to the time it reaches the surface.
- t depends on the initial velocity magnitude and the angle of the projectile:

$$t = \frac{2 \cdot v_{iy} \cdot sin\theta}{g} \tag{6.3}$$

About Acceleration

- In projectile motion, there is no acceleration in the horizontal direction. The acceleration, a, in the vertical direction is just due to gravity, also known as free fall:

$$a_x = 0 \tag{6.4}$$

$$a_y = -g \tag{6.5}$$

About Velocity

- The horizontal velocity remains constant, but the vertical velocity varies linearly, because the acceleration is constant. At any time, t, the velocity is:

$$v_{ix} = v_i \cdot cos\theta \tag{6.6}$$

$$v_{iy} = v_i \cdot sin\theta - g \cdot t \tag{6.7}$$

- We can also use th Pythagorean Theorem to find velocity

About Displacement

- The equation for the magnitude of the displacement is

$$\Delta r = \sqrt{x^2 + y^2} \tag{6.8}$$

About Parabolic Trajectory

- We can use the displacement equations in the x and y direction to obtain an equation for the parabolic form of a projectile motion:

$$y = tan\theta \cdot x - \frac{g}{2 \cdot v_i^2 \cdot cos^2\theta} \cdot x^2 \tag{6.9}$$

About Maximum Height

- The maximum height is reached when $v_{iy} = 0$. Using this we can rearrange the velocity equation to find the time it will take for the object to reach the maximum height

$$t_h = \frac{v_i \cdot sin\theta}{g} \tag{6.10}$$

- where t_h stands for the time it takes to reach maximum height. From the displacement equation we can find the maximum height

$$h = \frac{v_i^2 \cdot sin^2\theta}{2 \cdot g} \tag{6.11}$$

About Range

- The range of the motion is fixed by the condition y = 0. Using this we can rearrange the parabolic motion equation to find the range of the motion:

$$R = \frac{v_i^2 \cdot sin^2 2\theta}{g} \tag{6.12}$$

6.2 Rotational Kinematics

- Rotational motion is an important part of everyday life. The rotation of the Earth creates the cycle of day and night, the rotation of wheels enables easy vehicular motion, and modern technology depends on circular motion in a variety of contexts.
- Angular displacement θ is the distance an object travels on a circular path and is often measured in radians.
- Angular velocity is the angular displacement in a given unit of time. It is measured in radians per second.
- Angular acceleration is the change in angular velocity per unit time.
- The kinematics of rotational motion describes the relationships among rotation angle, angular velocity, angular acceleration, and time. Let us start by finding an equation relating ω, α, and t. To determine this equation, we recall a familiar kinematic equation for translational, or straight-line, motion:

$$v = v_0 + at \tag{6.13}$$

- As in linear kinematics, we assume a is constant, which means that angular acceleration α is also a constant, because $a = r\alpha$. Now, let us substitute $v = r\omega$ and $a = r\alpha$ into the linear equation above:

$$r\omega = r\omega_0 + r\alpha t \tag{6.14}$$

- The radius r cancels in the equation, yielding

$$\omega = \omega_0 + \alpha t \tag{6.15}$$

Constant Linear Acceleration	Constant Angular Acceleration	Constant
$v = v_i + at$	$\omega = \omega_0 + \alpha t$	a and α
$s = \frac{1}{2}(v_i + v)t$	$\theta = \frac{1}{2}(\omega_0 + \omega)t$	-
$s = v_i t + \frac{1}{2}at^2$	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$	a and α.
$v^2 = v_i^2 + 2as$	$\omega^2 = \omega_0^2 + 2\alpha\theta$	a and α.
$s = vt - \frac{1}{2}at^2$	$\theta = \omega t - \frac{1}{2}\alpha t^2$	a and α

- This last equation is a kinematic relationship among ω, α, and t - that is, it describes their relationship without reference to forces or masses that may affect rotation.
- The equations of motion with constant angular acceleration are related to the equations of motion with constant linear acceleration as shown in the above table:

6.3 Rotational Dynamics

- The moment of inertia of a body is a measure of the manner in which the mass of that body is distributed in relation to the axis about which that body is rotating.
- The moment of inertia dependent on: mass of the body, size of the body, shape of the body and which axis is being considered.
- Linear and Angular Variables Related A point in a rigid rotating body, at a perpendicular distance r from the rotation axis, moves in a circle with radius r. If the body rotates through an angle θ, the point moves along an arc with length s given by

$$s = \theta r \tag{6.16}$$

- The linear velocity $\vec{v}$ of the point is tangent to the circle; the point's linear speed v is given by

$$v = \omega r \tag{6.17}$$

- The linear acceleration $\vec{a}$ of the point has both tangential and radial components.
- The tangential component is

$$a_t = \alpha r \tag{6.18}$$

- The radial component $\vec{a}$ is

$$a_r = \frac{v^2}{r} = \omega^2 r \tag{6.19}$$

Rotational Kinetic Energy and Rotational Inertia

- **If the point moves in uniform circular motion, the period T of the motion for the point and the body is**

$$T = \frac{2\pi r}{v} = \frac{2\pi}{\omega} \tag{6.20}$$

- **The kinetic energy K of a rigid body rotating about a fixed axis is given by**

$$K = \frac{1}{2} I \omega^2 \tag{6.21}$$

The Parallel-Axis Theorem

- **The parallel-axis theorem relates the rotational inertia I of a body about any axis to that of the same body about a parallel axis through the center of mass:**

$$I = I_{com} + Mh^2 \tag{6.22}$$

- **Here h is the perpendicular distance between the two axes, and I_{com} is the rotational inertia of the body about the axis through the com.**
- **Torque is a turning or twisting action on a body about a rotation axis due to a force $\vec{F}$. If $\vec{F}$ is exerted at a point given by the position vector $\vec{r}$ relative to the axis, then the magnitude of the torque is**

$$\tau = rF_t = r_\perp F = rF sin\phi \tag{6.23}$$

6.4 Newton's Law of Universal Gravitation

- **Newton's law of universal gravitation states that if two masses M_1 and M_2 are a distance r apart, the gravitational force F between them is proportional to each of the masses, and decreases as they move apart by an inverse square relationship:**

$$F = \frac{GM_1M_2}{r^2} \tag{6.24}$$

- **Here M_1 and M_2 are the masses of the particles, r is the distance between them, and G is the gravitational constant, with a value that is now known to be $G = 6.67 \times 10^{-11} m^3/kg.s^2$.**
- **You can calculate the value of g at any distance above the surface of the Earth using:**

$$g = G\frac{M}{r^2} \tag{6.25}$$

- **Kepler's Laws The motion of satellites, both natural and artificial, is governed by these laws:**

1 . The law of orbits. All planets move in elliptical orbits with the Sun at one focus.

2 . The law of areas. A line joining any planet to the Sun sweeps out equal areas in equal time intervals. (This statement is equivalent to conservation of angular momentum.)

3 The law of periods. The square of the period T of any planet is proportional to the cube of the semimajor axis a of its orbit. For circular orbits with radius r,

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3 \tag{6.26}$$

- **You can use Kepler's laws of planetry motion to detrmine the period of any planet.**
- **You can determine the period of a satellite around a planet using $T = \frac{2\pi}{\omega}$**

Unit Summary Questions
Multiple Choice Questions

Choose the correct answer from the choice of each questions

1. A stone is just released from the window of a train moving along a horizontal straight track. The stone will hit the ground following?

(a) Hyperbolic path

(b) Straight path.

(c) Circular path.

(d) Parabolic path.

2. A bullet is dropped from the same height when another bullet is red horizontally. They will hit the ground?

(a) Simultaneously

(b) Depends on the observer

(c) One after the other

(d) None of the above

3. A bomb is dropped from an aeroplane moving horizontally at a constant speed. When air resistance is taken into consideration, the bomb

(a) Flies with the aeroplane

(b) Falls to earth behind the aeroplane

(c) Falls to earth ahead of the plane

(d) Falls to earth exactly below the aeroplane

4. The maximum range of gum on horizontal terrain is 16 km. If $g = 10m/s^2$. What must be the muzzle velocity of the shell?

(a) 400m/s

(b) 100m/s

(c) 200m/s

(d) 50m/s

5. An aeroplane flying 490 m above ground level at 100 m/s, releases a block. How far on the ground will it strike?

(a) 2 km

(b) 0.1 km

(c) 1 km

(d) None of the above

6. A man projects a coin upwards from the gate of a uniformly moving train. The path of coin for the man will be

(a) Vertical straight line

(b) Inclined straight line

(c) Parabolic

(d) Horizontal straight line

7. A particle A is dropped from a height and another particle B is thrown in a horizontal direction with the speed of 5m/sec from the same height. The correct statement is

(a) Particle B will reach the ground first

(b) Both particles will reach the ground with the same speed

(c) Particle A will reach the ground first

(d) Both particles will reach the ground simultaneously

8. A particle moves in a plane with constant acceleration in a direction from the initial velocity. The path of the particle will be

(a) A parabola

(b) An ellipse

(c) A straight line

(d) An arc of a circle

9. An aeroplane moving horizontally with a speed of 720 km/h drops a food packet while flying at a height of 396.9m. The time taken by the food packet to reach the ground and its horizontal range is

(a) 9 sec and 1800m

(b) 5 sec and 500m

(c) 8 sec and 1500m

(d) 3 sec and 2000m

10. At the height 80 m, an aeroplane is moving with 150 m/s. A bomb is dropped from it so as to hit a target. At what distance from the target should the bomb be dropped

(a) 600m

(b) 605.3m

(c) 80m

(d) 230m

11. When seen from below, the blades of a ceiling fan are seen to be revolving anticlockwise and their speed is decreasing. Select the correct statement about the directions of its angular velocity and angular acceleration.

(a) Angular velocity upwards, angular acceleration downwards.

(b) Angular velocity downwards, angular acceleration upwards.

(c) Both, angular velocity and angular acceleration, upwards.

(d) Both, angular velocity and angular acceleration, downwards

12. The moment of inertia of a body does not depend upon the

(a) mass of the body

(b) position of the axis of rotation

(c) distribution of the mass

(d) the angular acceleration of the body

13. The SI unit of moment of inertia is

(a) $gram - cm^2$

(b) $kg - m^2$

(c) kg/m^2

(d) kg-m

14. The dimensional formula for moment of inertia of a body is

(a) $L^0M^1T^{-2}$

(b) $L^2M^1T^0$

(c) $L^1M^1T^{-1}$

(d) $L^0M^2T^{-1}$

15. Moment of inertia depends upon

(a) position of axis of rotation

(b) distribution of particles

(c) mass

(d) all of these

16. The physical quantity in translational motion, which analogous to torque in rotational motion is

(a) Mass

(b) Linear Momentum

(c) Force

(d) Work

17. Torque per unit moment of inertia is

(a) Angular velocity

(b) Radius of gyration

(c) Angular displacement

(d) Angular acceleration

18. Moment of inertia depends upon

(a) position of axis of rotation

(b) distribution of particles

(c) mass

(d) all of these

19. Moment of inertia depends upon

(a) position of axis of rotation

(b) distribution of particles

(c) mass

(d) all of these

20. A torque of 100 N-m acting on a wheel at rest, rotates it through 200 radian in 10s. What is the moment of inertia of the wheel?

(a) $10kg-m^2$

(b) $15kg-m^2$

(c) $20kg-m^2$

(d) $25kg-m^2$

21. A vault is opened by applying a force of 300 N perpendicular to the plane of the door, 0.80 m from the hinges. Find the torque due to this force about an axis through the hinges.

(a) 120N.m.

(b) 240N.m.

(c) 300N.m.

(d) 360N.m

22. A 3.0-m rod is pivoted about its left end. A force of 6.0 N is applied perpendicular to the rod at a distance of 1.2 m from the pivot causing a ccw torque, and a force of 5.2 N is applied at the end of the rod 3.0 m from the pivot. The 5.2 N is at an angle of 30° to the rod and causes a cw torque. What is the net torque about the pivot?

(a) 15N.m

(b) 0N.m

(c) -6.3N.m

(d) -0.6N.m

23. A bucket of water with total mass 23 kg is attached to a rope, which in turn, is wound around a 0.050-m radius cylinder at the top of a well. A crank with a turning radius of 0.25 m is attached to the end of the cylinder. What minimum force directed perpendicular to the crank handle is required to just raise the bucket? (Assume the rope's mass is negligible, that cylinder turns on frictionless bearings, and that $g = 9.8m/s^2$

(a) 45N

(b) 68N

(c) 90N

(d) 135N

24. Masses are distributed in the x,y-plane as follows: 6.0 kg at (0.0, 0.0) m, 4.0 kg at (2.0, 0.0) m, and 5.0 kg at (2.0, 3.0) m. What is the x-coordinate of the center of gravity of this system of masses?

(a) 18m

(b) 2.0m

(c) 1.2m

(d) 1.0m

25. A uniform, horizontal beam of length 6.0 m and weight 120 N is attached at one end to a wall by a pin connection (so that it may rotate). A cable attached to the wall above the pin supports the opposite end.The cable makes an angle of 60° with the horizontal. What is the tension in the cable needed to maintain the beam in equilibrium?

(a) 35N

(b) 69N

(c) 60N

(d) 120N

26. A uniform beam of length 4.0 m and weight 100 N is mounted on an axle at one end perpendicular to the length of the beam. A rope is attached to the end of the beam at the other end from the axle and the beamis lifted by the rope so that the beam makes an angle of 30° with the horizontal. What is the tension in the rope if it is straight up?

(a) 50N

(b) 87N

(c) 100N

(d) 200N

27. A 4.0-kg mass is placed at (3.0, 4.0) m, and a 6.0-kg mass is placed at (3.0, -4.0) m. What is the moment of inertia of this system of masses about the y-axis?

(a) $160 kg.m^2$

(b) $90 kg.m^2$

(c) $250 kg.m^2$

(d) $180 kg.m^2$

28. If a net torque is applied to an object, that object will experience:

(a) a constant angular speed.

(b) an angular acceleration.

(c) a constant moment of inertia.

(d) an increasing moment of inertia.

29. According to Newton's second law, the angular acceleration experienced by an object is directly proportional to:

(a) its moment of inertia.

(b) the net applied torque.

(c) the object's size.

(d) choices a and b above are both valid.

30. The Earth moves about the Sun in an elliptical orbit. As the Earth moves closer to the Sun, which of the following best describes the Earth-Sun system's moment of inertia?

(a) decreases

(b) increases

(c) remains constant

(d) none of the above choices are valid

31. Newton's universal law of gravitation applies to

(a) small bodies only

(b) planets only

(c) both small and big bodies

(d) only valid for solar system

32. The value of G varies with

(a) height above the earth's surface

(b) depth below the ground

(c) radius of the planet

(d) None of these

ower

33. Force of gravitational attraction is least

(a) at the equator

(b) at the poles

(c) at a point in between equator and any pole

(d) None of these

34. The ratio of the inertial mass to gravitational mass is equal to

(a) 0.5

(b) 1

(c) 2

(d) no fixed number

35. Two spheres of masses m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity 3. The gravitational force will now be

(a) 3F

(b) F

(c) F/3

(d) F/9

36. In some region, the gravitational field is zero. The gravitational potential in this region.

(a) must be variable

(b) must be constant

(c) cannot be zero

(d) must be zero

37. In a gravitational field, at a point where the gravitational potential is zero

(a) the gravitational field is necessarily zero

(b) the gravitational field is not necessarily zero

(c) any value between one and infinite

(d) None of these

38. Who among the following gave first the experimental value of G

(a) Cavendish

(b) Copernicus

(c) Brok Taylor

(d) None of these

39. If m_1 and m_2 are masses of particles, r is the distance between them and G is gravitational constant then by Newton's law of gravitation, F=

(a) $G\frac{m_1}{m_2 r}$

(b) $G\frac{m_1 m_2}{r}$

(c) $G\frac{m_1 m_2}{r^2}$

(d) $G\frac{m_1 m_2}{r^3}$

Answer Sheet

I. Multiple Choice

1. D	2. B	3. B	4. A	5. C
6. A	7. D	8. A	9. A	10. A
11. A	12. D	13. B	14. B	15. D
16. C	17. D	18. C	19. C	20. D
21. B	22. D	23. A	24. C	25. B
26. A	27. B	28. B	29. B	30. A
31. C	32. D	33. A	34. C	35. B
36. B	37. A	38. A	39. C	____

Chapter 7

Electrostatics

7.1 Electric Charge

- **The structure of atoms can be described in terms of three particles: the negatively charged electron, the positively charged proton, and the uncharged neutron. The proton and neutron are combinations of other entities**
- **Electric charge is an intrinsic characteristic of the fundamental particles making up those objects; that is, it is a property that comes automatically with those particles wherever they exist.**
- **Charges with the same sign repel each other, and charges with opposite signs attract each other. An object with equal amounts of the two kinds of charge is electrically neutral, whereas one with an imbalance is electrically charged.**
- **Conductors are materials in which a significant number of charged particles (electrons in metals) are free to move. The charged particles in nonconductors, or insulators, are not free to move.**
- **The SI unit of charge is the coulomb (C). It is defined in terms of the unit of current, the ampere (A), as the charge passing a particular point in 1 second when there is a current of 1 ampere at that point:** $1C = (1A)(1s)$
- **Conservation of charge: The algebraic sum of all the electric charges in any closed system is constant. Charge can be transferred from one object to another, and that is the only way in which an object can acquire a net charge.**

- **Coulomb's Law** describes the electrostatic force between small (point) electric charges q_1 and q_2 at rest (or nearly at rest) and separated by a distance r:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2} \tag{7.1}$$

- Here $\varepsilon_0 = 8.85 \times 10^{-22} C^2/N.m^2$ is the **permittivity constant**, and $1/4\pi\varepsilon_0 = k = 8.99 \times 10^9 N.m^2/C^2$
- The algebraic sum of all the electric charges in any closed system is constant.

7.2 Electric Force and Fields

- **Electric Field**: To explain the electrostatic force between two charges, we assume that each charge sets up an electric field in the space around it. The force acting on each charge is then due to the electric field set up at its location by the other charge.
- **Electric Field $\vec{E}$** at any point is defined in terms of the electrostatic force $\vec{F}$ that would be exerted on a positive test charge q_0 placed there:

$$\vec{E} = \frac{\vec{F}}{q_0}. \tag{7.2}$$

- **Electric Field Lines** provide a means for visualizing the direction and magnitude of electric fields. The electric field vector at any point is tangent to a field line through that point.
- The density of field lines in any region is proportional to the magnitude of the electric field in that region.
- Field lines originate on positive charges and terminate on negative charges.
- **Field Due to a Point Charges:** The magnitude of the electric field $\vec{E}$ set up by a

point charge q at a distance r from the charge is

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} \tag{7.3}$$

- **The direction of $\vec{E}$** is away from the point charge if the charge is positive and toward it if the charge is negative.
- **TheField Due to an Electric Dipole:** An electric dipole consists of two particles with charges of equal magnitude q but opposite sign, separated by a small distance d.
- **Their electric dipole moment $\vec{p}$** has magnitude qd and points from the negative charge to the positive charge.

- **The magnitude of the electric field** set up by the dipole at a distant point on the dipole axis (which runs through both charges) is

$$E = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3} \tag{7.4}$$

where z is the distance between the point and the center of the dipole.

- **Field Due to a Continuous Charge Distribution:** The electric field due to a continuous charge distribution is found by treating charge elements as point charges and then summing, via integration, the electric field vectors produced by all the charge elements to find the net vector.
- **Force on a Point Charge in an Electric Field:**When a point charge q is placed in an external electric field $\vec{E}$, the electrostatic force $\vec{F}$ that acts on the point charge is

$$\vec{F} = q\vec{E} \tag{7.5}$$

- Force $\vec{F}$ has the same direction as $\vec{E}$ if q is positive and the opposite direction if q is negative.

- **Dipole in an Electric Field:** When an electric dipole of dipole moment $\vec{p}$ is placed in an electric field $\vec{E}$, the field exerts a torque τ on the dipole:

$$\vec{\tau} = \vec{p} \times \vec{E}. \tag{7.6}$$

- The dipole has a potential energy U associated with its orientation in the field:

$$U = -\vec{p} \cdot \vec{E}. \tag{7.7}$$

- This potential energy is defined to be zero when $\vec{p}$ is perpendicular to $\vec{E}$; it is least (U =-pE) when $\vec{p}$ is aligned with $\vec{E}$ and greatest (U=pE) when $\vec{p}$ is directed opposite $\vec{E}$.

7.3 Electric Potential

- **Electric Potential Energy**:
- **The change ΔU** in the electric potential energy U of a point charge as the charge moves from an initial point i to a final point f in an electric field is.

$$\Delta U = U_f - U_i = -W \tag{7.8}$$

where W is the work done by the electrostatic force (due to the external electric field) on the point charge during the move from i to f.

- If the potential energy is defined to be zero at infinity, the electric potential energy U of the point charge at a particular point is

$$U = -W_\infty \tag{7.9}$$

- **Here W_∞ is the work done by the electrostatic force on the point charge as the charge moves from infinity to the particular point.**
- **Electric Potential Difference and Electric Potential: We define the potential difference ΔV between two points i and f in an electric field as**

$$\Delta V = V_f - V_i = -\frac{W}{q}. \tag{7.10}$$

where q is the charge of a particle on which work W is done by the electric field as the particle moves from point i to point f.

- **The potential at a point is defined as**

$$V = -\frac{W_\infty}{q} \tag{7.11}$$

- **The SI unit of potential is the volt: 1 volt = 1 joule per coulomb.**
- **Potential and potential difference can also be written in terms of the electric potential energy U of a particle of charge q in an electric field:**

$$V = \frac{U}{q} \tag{7.12}$$

$$\Delta V = V_f - V_i = \frac{U_f}{q} - \frac{U_i}{q} = \frac{\Delta U}{q}. \tag{7.13}$$

- **Potential Due to Point Charges: The electric potential due to a single point charge at a distance r from that point charge is**

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}, \tag{7.14}$$

where V has the same sign as q.

- **The potential due to a collection of point charges is**

$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q}{r}. \tag{7.15}$$

- **Potential Due to an Electric Dipole: At a distance r from an electric dipole with dipole moment magnitude p = qd, the electric potential of the dipole is**

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p cos\theta}{r^2} \tag{7.16}$$

- **Electric Potential Energy of a System of Point Charges: is equal to the work needed to assemble the system with the charges initially at rest and infinitely distant from each other. For two charges at separation r,**

$$U = W = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r} \tag{7.17}$$

7.4 Capacitor and Capacitance

- **A capacitor is consists of two isolated conductors (the plates) with charges +q and -q .**
- **The capacitance C of any capacitor is the ratio of the magnitude of the charge q on either plate to the magnitude of potential difference V between them:**

$$C = \frac{q}{V}, \tag{7.18}$$

where V is the potential difference between the plates.

- **The Parallel-Plate Capacitor The capacitance of two parallel metal plates of area**

A separated by distance d is

$$C = \frac{\varepsilon_0 A}{d}. \tag{7.19}$$

where $\varepsilon_0 = 8.85 \times 10^{-12} C^2/N \cdot m^2$ is a constant called the permittivity of free space.

- A cylindrical capacitor (two long coaxial cylinders) of length L and radii a and b has capacitance

$$C = 2\pi\varepsilon_0 \frac{L}{ln(b/a)}. \tag{7.20}$$

- A spherical capacitor with concentric spherical plates of radii a and b has capacitance

$$C = 4\pi\varepsilon_0 \frac{ab}{b-a}. \tag{7.21}$$

- An isolated sphere of radius R has capacitance

$$C = 4\pi\varepsilon_0 R. \tag{7.22}$$

- **Capacitors in Parallel and in Series:**
- The equivalent capacitance of a parallel combination of capacitors is

$$C_{eq} = C_1 + C_2 + C_3 + \ldots \tag{7.23}$$

- If two or more capacitors are connected in series, the equivalent capacitance of the series combination is

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \tag{7.24}$$

- **Energy Stored in a Charged Capacitor:**

- **Three equivalent expressions for calculating the energy stored in a charged capacitor are**

$$U = \frac{1}{2}qV = \frac{1}{2}CV^2 = \frac{q^2}{2C} \tag{7.25}$$

- **Capacitance with a Dielectric:** **When a nonconducting material, called a dielectric, is placed between the plates of a capacitor, the capacitance is multiplied by the factor k, which is called the dielectric constant, a property of the dielectric material.**
- **The capacitance of a parallel-plate capacitor filled with a dielectric is**

$$C = k\pi\varepsilon_0\frac{A}{d}. \tag{7.26}$$

Multiple Choice Questions

Choose the correct answer from the choice of each questions

1. Doug rubs a piece of fur on a hard rubber rod, giving the rod a negative charge. What happens?

(a) Protons are removed from the rod.

(b) Electrons are added to the rod.

(c) The fur is also charged negatively.

(d) The fur is left neutral.

2. A repelling force must occur between two charged objects under which conditions?

(a) Charges are of unlike signs.

(b) Charges are of like signs.

(c) Charges are of equal magnitude.

(d) **Charges are of unequal magnitude.**

3. When a glass rod is rubbed with silk, which of the following statements best describes what happens?

(a) **Electrons are removed from the rod.**

(b) **Protons are removed from the silk.**

(c) **The silk is charged positively.**

(d) **The silk remains neutral.**

4. A metallic object holds a charge of $(-3.810^{-6}C$**. What total number of electrons does this represent?** $(e = 1.610^{-19}C$ **is the magnitude of the electronic charge.)**

(a) $4.2x10^{14}$

(b) $6.1x10^{13}$

(c) $2.4x10^{13}$

(d) $1.6x10^{14}$

5. When charging two objects by rubbing them together:

(a) **Neither may be a conductor.**

(b) **They must be made of different material.**

(c) **They will sometimes end up with both being positively charged.**

(d) **The heat produced by friction is a necessary part of this process.**

6. Who was the first to determine the electron's charge?

(a) **Franklin**

(b) **Coulomb**

(c) **Millikan**

(d) **Faraday**

7. An uncharged conductor is supported by an insulating stand. I pass a positively charged rod near the left end of the conductor, but do not touch it. The right end of the conductor will be:

(a) negative.

(b) positive.

(c) neutral.

(d) attracted.

8. Of the following substances, which one contains the highest density of free electrons?

(a) hard rubber

(b) iron

(c) amber

(d) glass

9. Which of the following best characterizes electrical insulators?

(a) charges on the surface don't move

(b) high tensile strength

(c) electric charges move freely

(d) good heat conductors

10.If body P, with a positive charge, is placed in contact with body Q (initially uncharged), what will be the nature of the charge left on Q?

(a) must be equal in magnitude to that on P

(b) must be negative

(c) must be positive

(d) must be greater in magnitude than that on P

11.I wish to use a positively charged rod to charge a ball by induction. Which statement is correct?

(a) The charge on the ball will be positive.

(b) The ball must be a conductor.

(c) The ball must be an insulator that is connected temporarily to the ground.

(d) The ball is charged as the area of contact between the two increases.

12.Two point charges are 4 cm apart. They are moved to a new separation of 2 cm. By what factor does the resulting mutual force between them change?

(a) 1/2

(b) 2

(c) 1/4

(d) 4

13.If the distance between two point charges is tripled, the mutual force between them will be changed by what factor?

(a) 9.0

(b) 3.0

(c) 0.33

(d) 1/9

14.The constant k_e , which appears in Coulomb's law formula, is equivalent dimensionally to which of the following?

(a) $N.m/C$

(b) N/C

(c) $N.m^2/C^2$

(d) N/C^2

15.Two equal charges, each Q, are separated by some distance. What third charge would need to be placed half way between the two charges so that the net force on each charge would be zero?

(a) **-Q**

(b) **-Q/2**

(c) **-Q/4**

(d) **-Q/8**

16.A 6.0 µC charge is placed at the origin and a second charge is placed on the x-axis at x = 0.30 m. If the resulting force on the second charge is 5.4 N in the positive x-direction, what is the value of its charge?

(a) $9.0/muC$

(b) $9.0nC$

(c) $-9.0\mu C$

(d) $-9.0nC$

17.Electric field is dimensionally equivalent to which of the following?

(a) $N.m/C$

(b) N/C

(c) $N.m^2/C^2$

(d) N/C^2

18.An electron with a charge value of 1.610^{-19} **C is moving in the presence of an electric field of 400 N/C. What force does the electron experience?**

(a) $2.3x10^{-22}N$

(b) $1.9x10^{-21}N$

(c) $6.4x10^{-17}N$

(d) $4.9x10^{-17}N$

19.The electric field of a point charge has an inverse$---------$**behavior.**

(a) $r^{1/2}$

(b) r

(c) r^2

(d) r^3

20.Q_1 **has 50 electric field lines radiating outward and** Q_2 **has 100 field lines converging inward. What is the ratio** Q_1/Q_2 **?**

(a) 2

(b) -2

(c) 1/2

(d) -1/2

21.Relative distribution of charge density on the surface of a conducting solid depends on:

(a) the shape of the conductor.

(b) mass density of the conductor.

(c) type of metal of which the conductor is made.

(d) strength of the earth's gravitational field.

22.The unit of electrical potential, the volt, is dimensionally equivalent to:

(a) $J.C.$

(b) J/C

(c) $C/J.$

(d) $F.C$**.**

23.The quantity of electrical potential, the volt, is dimensionally equivalent to:

(a) force/charge

(b) force × charge.

(c) electric field × distance.

(d) electric field/distance.

24.A free electron is in an electric field. With respect to the field, it experiences a force acting:

(a) parallel.

(b) anti-parallel (opposite in direction).

(c) perpendicular.

(d) along a constant potential line.

25.A uniform electric field, with a magnitude of 600 N/C, is directed parallel to the positive x-axis. If the potential at x = 3.0 m is 1 000 V, what is the potential at x = 1.0 m?

(a) 400V

(b) 1600V

(c) 2200V

(d) 2500V

26.In which case does an electric field do positive work on a charged particle?

(a) A negative charge moves opposite to the direction of the electric field.

(b) A positive charge is moved to a point of higher potential energy.

(c) A positive charge completes one circular path around a stationary positive charge.

(d) A positive charge completes one elliptical path around a stationary positive charge.

27.If the distance between two isolated parallel plates that are oppositely charged is doubled, the electric field between the plates is essentially unchanged. However, the:

(a) potential difference between the plates will double.

(b) charge on each plate will double.

(c) force on a charged particle halfway between the plates will get twice as small.

(d) force on a charged particle halfway between the plates will get four times as small.

28.A 9.0-V battery moves 20 mC of charge through a circuit running from its positive terminal to its negative terminal. How much energy was delivered to the circuit?

(a) $2.2mJ$

(b) $0.020J$

(c) $0.18J$**.**

(d) $4.5x10^3J$

29.If the distance between two negative point charges is increased by a factor of three, the resultant potential energy is what factor times the initial potential energy?

(a) 3.0

(b) 9.0

(c) 1/3

(d) 1/9

30.Which of the following characteristics are held in common by both gravitational and electrostatic forces when dealing with either point masses or charges?

(a) inverse square distance law applies

(b) forces are conservative

(c) potential energy is a function of distance of separation

(d) all of the above choices are valid

31.Find the potential at 0.15 m from a point charge of $6\mu C.(k_e = 8.99 \times 10^9 N \cdot m^2/C^2)$

(a) $5.4x10^4V$

(b) $3.6x10^5V$

(c) $2.4x10^6V$

(d) $1.2x10^7V$

32.At which location will the electric field between the two parallel plates of a charged capacitor be the strongest in magnitude?

(a) near the positive plate

(b) near the negative plate

(c) midway between the two plates at their ends

(d) midway between the two plates nearest their center

33.Which of the following is equivalent to the SI unit of capacitance (F)?

(a) V/C

(b) $V.C.$

(c) J/V

(d) $C/V.$

34.Increasing the voltage across the two plates of a capacitor will produce what effect on the capacitor?

(a) increase charge

(b) decrease charge

(c) increase capacitance

(d) decrease capacitance

35.A parallel-plate capacitor has a capacitance of $20\mu F.$ What potential difference across the plates is required to store $7.2x10^{-4}C$ on this capacitor?

(a) $36V$

(b) $2.2x10^{-2}V.$

(c) $1.4x10^{-8}V$

(d) $68V.$

36.A $20\mu F$ **capacitor is attached across a 1000-V power supply. What is the net charge on the capacitor?**

(a) $10mC$

(b) $20mC$

(c) $40mC$

(d) none of the above

37.Doubling the voltage across a parallel plate capacitor does not double which of the following?

(a) the charge

(b) the electric field between the plates

(c) the energy stored

(d) both a and b

38.Increasing the separation of the two charged parallel plates of a capacitor, which are disconnected from a battery, will produce what effect on the capacitor?

(a) increase charge

(b) decrease charge

(c) increase capacitance

(d) decrease capacitance

39.Three capacitors of 1.0, 1.5, and 2.0μ **F are connected in series. Find the combined capacitance.**

(a) $4.5\mu F$

(b) $4.0\mu F$.

(c) $2.2\mu F$

(d) $0.46\mu F$.

40.If three 4.0μF capacitors are connected in parallel, what is the combined capacitance?

(a) $12\mu F$

(b) $0.75\mu F$

(c) $8.0\mu F$

(d) $0.46\mu F$

Answer Sheet

I. Multiple Choice

1. D	2. B	3. B	4. A	5. C
6. A	7. D	8. A	9. A	10. A
11. A	12. D	13. B	14. B	15. D
16. C	17. D	18. C	19. C	20. D
21. B	22. D	23. A	24. C	25. B
26. A	27. B	28. B	29. B	30. A
31. C	32. D	33. A	34. C	35. B
36. B	37. A	38. A	39. C	40. D

Chapter 8

Current Electricity

8.1 Electric Current

- **An Electric Current is a flow of charge or the rate flow of electric charge.**
- **Ampere is the SI unit of electric current (1 ampere=1 coulomb per second=1A=1C/s).**
- **An electric current I in a conductor is defined by**

$$I = \frac{Q}{t}. \tag{8.1}$$

where Q is the charge that passes through a cross section of the conductor in time t.

- **Current density is the amount of charge per unit time that flows through a unit area of a chosen cross section.**
- **The formula for current desity (J) is given as,**

$$J = \frac{I}{A} \tag{8.2}$$

Where, I = current flowing through the conductor in Amperes

A = cross-sectional area in m^2.

- **Current density is expressed in A/m^2.**
- **The number of charge carriers in a length L of the wire is nAL, where n is the number of carriers per unit volume.**
- **The total charge of the carriers in the length L, each with charge e, is then**

$$q = (nAL)e. \tag{8.3}$$

where n is the number of carriers per unit volume

A is wires cross-sectional area

L is a length of wires

e is the charge of electron.

- **Because the carriers all move along the wire with speed v_d, this total charge moves through any cross section of the wire in the time interval**

$$t = \frac{L}{v_d}. \tag{8.4}$$

- **The current in a conductor is related to the motion of the charge carriers by**

$$I = nqv_dA. \tag{8.5}$$

where n is the number of mobile charge carriers per unit volume, q is the charge on each carrier, v_d is the drift speed of the charges, and A is the cross-sectional area of the conductor.

8.2 Ohm's Law and Electrical Resistance

- **The resistance R of a conductor is defined as the ratio of the potential difference**

across the conductor to the current in it:

$$R = \frac{V}{I} \tag{8.6}$$

- **The SI unit for resistance is the volt per ampere.This combination occurs so often that we give it a special name, the ohm (symbol Ω); that is,**

$$1\Omega = 1V/A.$$

- **A conductor whose function in a circuit is to provide a specified resistance is called a resistor.**
- **Ohm's law describes many conductors, for which the applied voltage is directly proportional to the current it causes. The proportionality constant is the resistance:**

$$V = IR \tag{8.7}$$

- **If a conductor has length l and cross-sectional area A, its resistance is**

$$R = \rho\frac{l}{A} \tag{8.8}$$

where r is an intrinsic property of the conductor called the electrical resistivity.

- **The SI unit of resistivity is the ohm meter** (Ωm).
- **Over a limited temperature range, the resistivity of a conductor varies with temperature according to the expression**

$$\rho = \rho_0[1 + \alpha(T - T_0)] \tag{8.9}$$

where α is the temperature coefficient of resistivity and ρ_0 is the resistivity at some reference temperature T_0 (usually taken to be $20C$).

- The resistance of a conductor varies with temperature according to the expression

$$R = R_0[1 + \alpha(T - T_0)] \tag{8.10}$$

8.3 Combinations of Resistors

- Equivalent resistance of a series combination of resistors:The equivalent resistance of a series combination of resistors is the algebraic sum of the individual resistances and is always greater than any individual resistance.

$$R_{eq} = R_1 + R_2 + R_3 + ... \tag{8.11}$$

- When a potential difference V is applied across resistances connected in series, the resistances have identical currents i. The sum of the potential differences across the resistances is equal to the applied potential difference V.
- Equivalent resistance for resistors in parallel: For any number of resistors in parallel, the reciprocal of the equivalent resistance equals the sum of the reciprocals of their individual resistances:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... \tag{8.12}$$

- The equivalent resistance is always less than any individual resistance.

8.4 E.m.f and Internal Resistance of a Cell

- **“Electromotive force” is a poor term because emf is not a force, but an “energy per unit charge” quantity, like potential. The SI unit of emf is the same as the unit for potential, the volt (1V=1JC).**
- **The influence that moves charge from lower to higher potential (despite the electric-field forces in the opposite direction) is called electromotive force (abbreviated emf and pronounced “ee-em-eff”).**
- **Batteries, electric generators, solar cells, thermocouples, and fuel cells are all sources of emf. Each such device converts energy of some form (mechanical, chemical, thermal, and so on) into electrical potential energy.**
- **A voltmeter is an instrument that can measure the e.m.f. of a cell; it has two lead going to it, and one is connected to each terminal of the cell.**
- **An ideal emf device is one that lacks any internal resistance to the internal movement of charge from terminal to terminal. The potential difference between the terminals of an ideal emf device is equal to the emf of the device.**
- **A real emf device, such as any real battery, has internal resistance to the internal movement of charge.**
- **For the ideal source of emf that we have described, the potential difference V_{ab} is equal to the electromotive force ε**

$$\varepsilon = V_{ab} = IR. \quad (ideal\ source\ of\ e.m.f.) \tag{8.13}$$

- **Real sources of emf don’t behave exactly like the ideal sources we’ve described because charge that moves through the material of any real source encounters resistance. We call this the internal resistance of the source, denoted by r. If this resistance behaves according to Ohm’s law, r is constant.**
- **The current through r has an associated drop in potential equal to Ir. The terminal**

potential difference V_{ab} is then

$$V_{ab} = \varepsilon - Ir \quad (source\ with\ internal\ resistance) \tag{8.14}$$

- **The potential V_{ab}, called the terminal voltage, is less than the emf ε because of the term Ir representing the potential drop across the internal resistance r.**
- **The current in the external circuit is still determined by $V_{ab} = IR$. Combining this relationship with Equation 3.14, we find that $\varepsilon - Ir = IR$, and it follows that**

$$I = \frac{\varepsilon}{R+r} \quad (source\ with\ internal\ resistance) \tag{8.15}$$

- **That is, the current I equals the source emf ε, divided by the total circuit resistance $(R+r)$. Thus, we can describe the behavior of a source in terms of two properties: an emf ε, which supplies a constant potential difference that is independent of the current, and a series internal resistance r.**

8.5 Electric Energy and Power

- **When a charge q passes through the circuit element, the work done on the charge is equal to the product of q and the potential difference V_{ab} (work per unit charge).**
- **When V_{ab} is positive, a positive amount of work qV_{ab} is done on the charge as it "falls" from potential V_a to the lower potential V_b.**
- **If the current is I, then in a time interval Dt an amount of charge $\Delta Q = I\Delta t$ passes through. The work ΔW done on this amount of charge is**

$$\Delta W = V_{ab}\Delta Q = V_{ab}I\Delta t. \tag{8.16}$$

- **This work represents electrical energy transferred into the circuit element.**
- **The time rate of energy transfer is power, denoted by P.**
- **Dividing the preceding equation by Δt, we obtain the time rate at which the rest of the circuit delivers electrical energy to the circuit element:**

$$\frac{\Delta W}{\Delta t} = P = V_{ab}I. \tag{8.17}$$

- **When current flows through a resistor, electrical energy is transformed into thermal energy.**
- **We calculate the power dissipated through a resistor as follows: The potential difference across the resistor is $V_{ab} = IR$. From Equation 3.17, the electric power delivered to the resistor by the circuit is**

$$P = V_{ab}I = I^2R = \frac{V_{ab}^2}{R}. \tag{8.18}$$

- **Energy is being delivered to the external circuit, and the rate of its delivery to the circuit is given by Equation 3.18: $P = V_{ab}I$. For a source that can be described by an emf ε and an internal resistance r, we may use Equation 3.14: $V_{ab} = \varepsilon - Ir$. Multiplying this equation by I, we find that**

$$P = V_{ab}I = \varepsilon I - I^2 r. \tag{8.19}$$

8.6 Electric Installation and Safety Rules

- A person can be electrocuted by touching a live wire while in contact with ground. Such a hazard is often due to frayed insulation that exposes the conducting wire.
- Currents of 5 mA or less can cause a sensation of shock, but ordinarily do little or no damage.
- If the current is larger than about 10 mA, the hand muscles contract and the person may be unable to let go of the live wire.
- If a current of about 100 mA passes through the body for just a few seconds, it can be fatal. Such large currents paralyze the respiratory muscles.
- In some cases, currents of about 1 A through the body produce serious (and sometimes fatal) burns.
- As an additional safety feature for consumers, electrical equipment manufacturers now use electrical cords that have a third wire, called a case ground.
- Special power outlets called ground - fault interrupters (GFIs) are now being used in kitchens, bathrooms, basements, and other hazardous areas of new homes.
- They are designed to protect people from electrical shock by sensing small currents approximately 5 mA and greater leaking to ground.
- When current above this level is detected, the device shuts off (interrupts) the current in less than a millisecond.

Multiple Choice Questions

Choose the correct answer from the choice of each questions

1. A car battery is rated at $80A \cdot h$. An ampere-hour is a unit of:———
   (a) power
   (b) energy
   (c) current
   (d) charge
2. Current has units:———

(a) **kilowatt.hour**

(b) **coulom/second**

(c) **coulomb**

(d) **volt**

3. The units of resistivity are: ———

(a) **ohm**

(b) $ohm \cdot meter$

(c) **ohm/meter**

(d) $ohm/meter^2$

4. The rate at which electrical energy is used may be measured in:——

(a) $watt/second$

(b) $watt/cdotsecond$

(c) $watt$

(d) $joule \cdot second$

5. Which one of the following quantities is correctly matched to its unit?

(a) $Power \rightarrow kW \cdot h$

(b) $Energy \rightarrow kW$

(c) $Potentialdifference \rightarrow J/C$

(d) $Current \rightarrow A/s$

6. Current is a measure of:——

(a) **force that moves a charge past a point**

(b) **resistance to the movement of a charge past a point**

(c) **energy used to move a charge past a point**

(d) amount of charge that moves past a point per unit time

7. A 60-watt light bulb carries a current of 0.5 A. The total charge passing through it in one hour is:——

(a) $120C$

(b) $3600C$

(c) $3000C$

(d) $1800C$

8. A 10-ohm resistor has a constant current. If 1200 C of charge flow through it in 4 minutes what is the value of the current?

(a) $15A$

(b) $3.0A$

(c) $5.0A$

(d) $20A$

9. Two wires made of different materials have the same uniform current density. They carry the same current only if:——

(a) their lengths are the same

(b) their cross-sectional areas are the same

(c) both their lengths and cross-sectional areas are the same

(d) the potential differences across them are the same

10. A wire with a length of 150 m and a radius of 0.15 mm carries a current with a uniform current density of $2.8 \times 10^7 A/m^2$ **. The current is:——-**

(a) $0.63A^2$

(b) $2.0A$

(c) $5.9A^2$

(d) $296A$

11. If the potential difference across a resistor is doubled:——

(a) only the current is doubled

(b) only the current is halved

(c) only the resistance is doubled

(d) only the resistance is halved

12. The resistance of a rod does NOT depend on:——

(a) its temperature

(b) its length

(c) the shape of its (fixed) cross-sectional area

(d) its conductivity

13. A certain wire has resistance R. Another wire, of the same material, has half the length and half the diameter of the first wire. The resistance of the second wire is:——

(a) $R/4$

(b) $R/2$

(c) R

(d) $2R$

14. A current of 0.5 A exists in a 60-ohm lamp. The applied potential difference is:——

(a) $15V$

(b) $30V$

(c) $60V$

(d) $120V$

15. For an ohmic substance the resistivity is the proportionality constant for:——

(a) current and potential difference

(b) potential difference and electric field

(c) current and electric field

(d) current and cross-sectional area

16. For an ohmic substance, the resistivity depends on:——

(a) the electric field

(b) the potential difference

(c) the current density

(d) the electron mean free time

17. An ordinary light bulb is marked "60 W, 120 V". Its resistance is:——

(a) 240Ω

(b) 120Ω

(c) 180Ω

(d) 60Ω

18. A total resistance of 3.0Ω **is to be produced by combining an unknown resistor R with a** 12Ω **resistor. What is the value of R and how is it to be connected to the** 12Ω**resistor?**

(a) $4.0\Omega, parallel$

(b) $4.0\Omega, series$

(c) $2.4\Omega, parallel$

(d) $2.4\Omega, series$

19. Four $20-\Omega$ **resistors are connected in parallel and the combination is connected to a 20-V emf device. The current in the device is:——**

(a) $0.25A$

(b) $1.0A$

(c) $4.0A$

(d) $5.0A$

20. Four $20-\Omega$ **resistors are connected in parallel and the combination is connected to a 20-V emf device. The current in any one of the resistors is:——**

(a) $0.25A$

(b) $1.0A$

(c) $4.0A$

(d) $5.0A$

21. Two wires made of the same material have the same lengths but different diameters. They are connected in series to a battery. The quantity that is the same for the wires is:

(a) the end-to-end potential difference

(b) the current

(c) the current density

(d) the electric field

22. The resistance of resistor 1 is twice the resistance of resistor 2. The two are connected in parallel and a potential difference is maintained across the combination. Then:——

(a) the current in 1 is twice that in 2

(b) the current in 1 is half that in 2

(c) the potential difference across 1 is twice that across 2

(d) the potential difference across 1 is half that across 2

23. Resistor 1 has twice the resistance of resistor 2. The two are connected in parallel and a potential difference is maintained across the combination. The rate of thermal energy generation in 1 is:——-

(a) the same as that in 2

(b) twice that in 2

(c) half that in 2

(d) four times that in 2

24. The emf of a battery is equal to its terminal potential difference:———

(a) under all conditions

(b) only when the battery is being charged

(c) only when a large current is in the battery

(d) only when there is no current in the battery

25. A battery with an emf of 24 V is connected to a 6Ω **resistor. As a result, current of 3 A exists in the resistor. The terminal potential difference of the battery is:———**

(a) $0V$

(b) $18V$

(c) $12V$

(d) $6V$

26. Resistances of $2.0\Omega, 4.0\Omega$**, and** 6.0Ω **and a 24-V emf device are all in parallel. The current in the** 2.0Ω **resistor is:——**

(a) $12A$

(b) $4.0A$

(c) $2.4A$

(d) $2.0A$

27. Resistances of $2.0\Omega, 4.0\Omega$**, and** 6.0Ω **and a 24-V emf device are all in parallel. The current in the** 2.0Ω **resistor is:——**

(a) $4V$

(b) $8V$

(c) $12V$

(d) $24V$

28. A battery with an emf of 12 V and an internal resistance of 1Ω is used to charge a battery with an emf of 10 V and an internal resistance of 1Ω. The current in the circuit is:——-

(a) $1A$

(b) $2A$

(c) $4A$

(d) $11A$

29. A $3-\Omega$ and a $1.5-\Omega$ resistor are wired in parallel and the combination is wired in series to a $4-\Omega$ resistor and a 10-V emf device. The potential difference across the $3-\Omega$ resistor is:——-

(a) $2.0V$

(b) $6.0V$

(c) $8.0V$

(d) $10.0V$

30. Resistor 1 has twice the resistance of resistor 2. They are connected in parallel to a battery. The ratio of the thermal energy generation rate in 1 to that in 2 is:——-

(a) $1:4$

(b) $1:2$

(c) $1:1$

(d) $2:1$

31. Materials having resistance changes as voltage or current varies are called: ——-

(a) ohmic.

(b) inohmic.

(c) nonohmic.

(d) deohmic.

32.You measure a 25.0-V potential difference across a 5.00-Ω resistor. What is the current flowing through it?

(a) $125A$

(b) $5.00A$

(c) $4.00A$

(d) $1.00A$

33. The unit of electric current, the ampere, is equivalent to which of the following?

(a) $v \cdot \Omega$

(b) V/Ω

(c) $\Omega \cdot m$

(d) V/s

34. The unit of electric resistance, the ohm, is equivalent to which of the following?

(a) V/A

(b) $V \cdot m$

(c) A/s

(d) A/m

35.If a certain resistor obeys Ohm's law, its resistance will change:

(a) as the voltage across the resistor changes.

(b) as the current through the resistor changes.

(c) as the energy given off by the electrons in their collisions changes.

(d) none of the above, since resistance is a constant for the given resistor.

36. A 0.20-m-long metal rod has a radius of 1.0 cm and a resistance of $3.2\times10^{-5}\Omega$**. What is the resistivity of the metal?**

(a) $1.6\times10^{-8}\Omega\cdot m$

(b) $5.0\times10^{-8}\Omega\cdot m$

(c) $16\times10^{-8}\Omega\cdot m$

(d) $160\times10^{-8}\Omega\cdot m$

37. The temperature coefficient of resistivity for a "perfect" ohmic material would be:——-

(a) positive and constant.

(b) zero.

(c) negative.

(d) positive and uniformly increasing.

38.A 60-W light bulb is in a socket supplied with 120 V. What is the current in the bulb?

(a) $0.50A$

(b) $2.0A$

(c) $60A$

(d) $7200A$

39. The quantity volt is equivalent to which of the following?

(a) $J\cdot m$

(b) $J\cdot C$

(c) C/Ω

(d) J/C

40. Three resistors with values of $R_1, R_2 and R_3$, respectively, are connected in series. Which of the following expresses the total resistance, R_T, of the three resistors?

(a) $R_T = R_1 + R_2 + R_3$

(b) $R_T = (1/R_1 + 1/R_2 + 1/R_3)$

(c) $R_T = R_1 = R_2 = R_3$

(d) $R_T = (1/R_1 + 1/R_2 + 1/R_3)^{-1}$

Answer Sheet

I. Multiple Choice

1. D	2. B	3. B	4. C	5. C
6. D	7. D	8. A	9. B	10. B
11. A	12. C	13. D	14. B	15. A
16. D	17. A	18. A	19. C	20. B
21. B	22. B	23. C	24. D	25. B
26. A	27. A	28. A	29. A	30. B
31. C	32. B	33. B	34. A	35. D
36. B	37. B	38. A	39. D	40. A

Chapter 9

Electromagnetism

9.1 Magnetism

- **Magnetism is the force exerted by magnets when they attract or repel each other.**
- **Magnetism is caused by the motion of electric charges. Every substance is made up of tiny units called atoms. Each atom has electrons, particles that carry electric charges.**
- **Magnetism is a force of nature produced by moving electric charges.**
- **Magnetism is the class of physical attributes that are mediated by a magnetic field, which refers to the capacity to induce attractive and repulsive phenomena in other entities.**
- **A bar magnet has a north (N) pole and a south (S) pole.Two opposite poles attract each other, and two like poles repel each other.**
- **Magnetic materials have atoms that act as tiny magnets which we call domains.**
- **When the domains are lined up, then the material is magnetic.**
- **If the domains are arranged randomly, then the material losses its magnetism.**
- **Some materials can be used as magnetic shields to protect equipment from becoming magnetized.**

9.2 Concepts of Magnetic Field

- **Recall that an electric field surrounds any electric charge. In addition to containing an electric field, the region of space surrounding any moving electric charge also contains a magnetic field.**
- **A magnetic field also surrounds a magnetic substance making up a permanent magnet.**
- **A moving charge, or current, experiences a force in the presence of a magnetic field.**
- **Magnetic field is a region where a magnetic force may be exerted.**
- **Magnetic flux is a measure of the strength of a magnetic field over a given area.**
- **A magnetic Field $\vec{B}$ is produced by a magnetic charge. We can then define a magnetic field $\vec{B}$ to be a vector quantity that is directed along the zero-force axis.**
- **We can next measure the magnitude of $\vec{F}_B$ when $\vec{v}$ is directed perpendicular to that axis and then define the magnitude of $\vec{B}$ in terms of that force magnitude:**

$$B = \frac{F_B}{|q|v}, \tag{9.1}$$

- **Magnetic field strength at a point due to a current carrying wire. The relationship is given by the formula**

$$F = B \times I \times L \tag{9.2}$$

- **The SI unit of magnetic field is newton per coulomb-meter per second which is called Teslas (T).**

$$1T = 1\frac{N}{C.m/s} \tag{9.3}$$

- **A non-SI magnetic-field unit in common use, called the gauss (G), is related to the tesla through the conversion $1T = 10^4 G$.**

- **The magnetic field strength also known as magnetic flux density.**
- **Solenoid is a coil of wire in which a magnetic field is created by passing a current through it.**
- **A long solenoid of many closely spaced windings produces a nearly uniform field in its interior, midway between its ends, having the strength of the magnetic field in a solenoid is given by the formula:**

$$B = \mu_0 n I \tag{9.4}$$

where n, is the number of turns of wire per meter of length, μ_0, is the free permeability in a space, I, is the current flowing through the wire.

9.3 Magnetic Force

- **Magnetic Force is the force exerted between magnetic poles, producing magnetization.**
- **The force $\vec{F}_B$ acting on a charged particle moving with velocity $\vec{v}$ through a magnetic field $\vec{B}$ is always perpendicular to $\vec{v}$ and $\vec{B}$.**

$$\vec{F}_B = |q|\vec{v}_\perp \times \vec{B} = |q|\vec{v}\vec{B}sin\theta, \tag{9.5}$$

where $|q|$ is the magnitude of the charge and θ is the angle measured from the direction of $\vec{v}$ to the direction of $\vec{B}$.

- **The factors that determine the force are: the current, the length of the wire, and the strength of the magnet.**
- **Force on a segment of current-carrying wire in a uniform magnetic field is given by:**

$$\vec{F}_B = I\vec{L} \times \vec{B} \tag{9.6}$$

where $\vec{L}$ is a vector that points in the direction of the current I and has a magnitude

equal to the length L of the segment.

- **A convenient vector expression for the torque exerted on a loop placed in a uniform magnetic field $\vec{B}$ is**

$$\vec{\tau} = I\vec{A} \times \vec{B} \tag{9.7}$$

where $\vec{A}$, the vector, is perpendicular to the plane of the loop and has a magnitude equal to the area of the loop.

- **The product $I\vec{A}$ is defined to be the magnetic dipole moment $\vec{\mu}$ (often simply called the "magnetic moment") of the loop:**

$$\vec{\mu} = I\vec{A} \tag{9.8}$$

- **The SI unit of magnetic dipole moment is the $ampere - meter^2$ $(A \cdot m^2)$. If a coil of wire contains N loops of the same area, the magnetic moment of the coil is**

$$\vec{\mu}_{coil} = NI\vec{A} \tag{9.9}$$

- **We can express the torque exerted on a current-carrying loop in a magnetic field $\vec{B}$ as**

$$\vec{\tau} = \vec{\mu} \times \vec{B} \tag{9.10}$$

- **The potential energy of the system of a magnetic dipole in a magnetic field is**

$$U_B = -\vec{\mu} \cdot \vec{B} \tag{9.11}$$

- **In each case the energy due to the field is equal to the negative of the scalar product of the corresponding dipole moment and the field vector.**

- **If the dipole is stationary before and after the change in its orientation, then work W_a is**

$$W_a = U_f - U_i. \tag{9.12}$$

9.4 Electromagnetic Induction

- **Electromagnetic induction is the production of voltage across a conductor moving through a stationary magnetic field.**
- **Induced e.m.f. voltage produced by electromagnetic induction.**
- **We define the magnetic flux $\Delta\Phi_B$ through the element of area ΔA as**

$$\Delta\Phi_B = B_\perp \Delta A = B cos\phi \Delta A. \tag{9.13}$$

- **The SI unit of magnetic flux is the unit of magnetic field (1 T) times the unit of area $(1m^2)$ weber= 1 :**
  $(1T)(1m^2) = [1N/(A \cdot m)](1m^2) = 1N \cdot m/A = 1weber = 1Wb.$
- **Faraday's law of induction: The magnitude of the induced emf in a circuit equals the absolute value of the time rate of change of the magnetic flux through the circuit.**
- **In symbols, Faraday's law is**

$$\varepsilon = \left| \frac{\Delta\Phi_B}{\Delta t} \right| \tag{9.14}$$

- **If we have a coil with N identical turns, and the magnetic flux varies at the same rate through each turn, the induced emf's in the turns are all equal, are in series,**

and must be added. The total emf magnitude ε is then

$$\varepsilon = N\left|\frac{\Delta\Phi_B}{\Delta t}\right| \tag{9.15}$$

- **Lenz's law:The induced current in a loop is in the direction that creates a magnetic field that opposes the change in magnetic flux through the area enclosed by the loop.**
- **An Inductor is defined as a passive electronic component that stores energy in a magnetic field when electric current flows through the inductors coil.**
- **Inductance is the property in an electrical circuit where a change in the electric current through that circuit induces an e.m.f. that opposes the change in current.**
- **Self-inductance is the ratio of the electromotive force produced in a circuit by self induction to the rate of change of current producing it.**
- **Definition of self-inductance: The self-inductance L of a circuit is the magnitude of the self-induced emf ε per unit rate of change of current, so that:**

$$\varepsilon = L\left|\frac{\Delta I}{\Delta t}\right| \tag{9.16}$$

- **The inductance L is thus a measure of the flux linkage produced by the inductor per unit of current. The inductance of the inductor is then**

$$L = \frac{N\Phi_B}{I} \tag{9.17}$$

in which N is the number of turns.

- **The windings of the inductor are said to be linked by the shared flux, and the product $N\Phi_B$ is called the magnetic flux linkage.**
- **The SI unit of inductance is the $(T \cdot m^2/A)$. We call this thehenry (H)**
- **Mutual inductance is the ratio of the electromotive force in a circuit to the corre-**

sponding change of current in a neighboring circuit.

- The mutual inductance M of a pair of circuits is defined by:

$$\varepsilon_{mut} = \frac{M\Delta I}{\Delta t} \tag{9.18}$$

- **The inductance** of a circuit depends on **its size, shape, and number of turns**. For N turns close together, it is always proportional to N^2.
- **The inductance** also depends on the magnetic properties of the material enclosed by the circuit.
- **Alternating current(a.c.)** an electric current that periodically reverse direction.
- **Transformer** is a device that transfer electrical energy from one circuit to another, usually with a change of voltage.
- **A transformer** consists of two coils (usually called windings), electrically insulated from each other but wound on the same core.
- The winding to which power is supplied is called **the primary**; the winding from which power is delivered is called **the secondary**.
- **Transformers** used in **power-distribution systems** have soft iron cores.
- The main purpose of transformer is to change the size of a **voltage**.
- Relation of voltage to winding turns for a transformer, for an ideal transformer (with zero resistance),

$$\frac{V_{out}}{V_{in}} = \frac{N_s}{N_p} \tag{9.19}$$

- $V_{out} > V_{in}$, we have **step-up transformer**; $V_{out} < V_{in}$, we have **step-down transformer**.

Multiple Choice Questions

Choose the correct answer from the choice of each questions

1. Electrical charges and magnetic poles have many similarities, but one difference is:——

(a) opposite magnetic poles repel.

(b) one magnetic pole cannot create magnetic poles in other materials.

(c) a magnetic pole cannot be isolated.

(d) magnetic poles do not produce magnetic fields.

2. A soft magnetic material has which property?:———

(a) It cannot be magnetized.

(b) It is easy to magnetize.

(c) It is hard to magnetize.

(d) It attracts slowly moving charges.

3. Which of the following is not a hard magnetic material? ———

(a) iron

(b) cobalt

(c) nickel

(d) both b and c

4. The magnetic pole of the Earth nearest the geographic North Pole corresponds to which of the following?

(a) a magnetic north pole

(b) a magnetic south pole

(c) a magnetic arctic pole

(d) a magnetic Antarctic pole

5. An electron which moves with a speed of $3.0 \times 10^4 m/s$ **parallel to a uniform magnetic field of 0.40 T experiences a force of what magnitude?** $(e = 1.6 \times 10^{-19} C)$

(a) $4.8 \times 10^{-14}N$

(b) $1.9 \times 10^{-15}N$

(c) $2.2 \times 10^{-24}N$

(d) 0

6. The force on a charged particle created by its motion in a magnetic field is maximum at what angle between the particle velocity and field?

(a) 0^0

(b) 180^0

(c) 90^0

(d) 45^0

7. A proton moving at a speed of $3.8 \times 10^6 m/s$ **cuts across the lines of a magnetic field at an angle of** 70^0**. The strength of the field is** $0.25 \times 10^{-4}T$**. What is the magnitude of the force acting on the proton?** $(q_p = 1.6 \times 10^{-19}C)$

(a) $5.1 \times 10^{-18}N$

(b) $9.0 \times 10^{-18}N$

(c) $1.4 \times 10^{-17}N$

(d) $2.3 \times 10^{-17}N$

8. Different units can be used to measure the same physical quantity, differing only by some multiplicative factor. The cgs unit for magnetic field, the gauss, is equal to——- tesla.

(a) 10^4

(b) 10^{-4}

(c) 0.5

(d) These units do not measure the same physical quantity.

9. A 2.0-m wire segment carrying a current of 0.60 A oriented parallel to a uniform magnetic field of 0.50 T experiences a force of what magnitude?

(a) $6.7N$

(b) $0.30N$

(c) $0.15N$

(d) 0

10. A copper wire of length 25 cm is in a magnetic field of 0.20 T. If it has a mass of 10 g, what is the minimum current through the wire that would cause a magnetic force equal to its weight?

(a) $1.3A$

(b) $1.5A$

(c) $2.0A$

(d) $4.9A$

11. Which of the following devices makes use of an electromagnet?

(a) loudspeaker

(b) galvanometer

(c) both A and B

(d) None of the above.

12. The force exerted on a current-carrying wire located in an external magnetic field is directly proportional to which of the following?

(a) current strength

(b) field strength

(c) both A and B

(d) None of the above are valid.

13. The direction of the force on a current carrying wire located in an external magnetic field is which of the following?

(a) **perpendicular to the current**

(b) **perpendicular to the field**

(c) **Both choices (a) and (b) are valid.**

(d) **None of the above are valid.**

14. A current-carrying wire of length 50 cm is positioned perpendicular to a uniform magnetic field. If the current is 10.0 A and it is determined that there is a resultant force of 3.0 N on the wire due to the interaction of the current and field, what is the magnetic field strength?

(a) $0.60T$

(b) $1.5T$

(c) $1.8 \times 10^{-3}T$

(d) $6.7 \times 10^{-3}T$

15. A horizontal wire of length 3.0 m carries a current of 6.0 A and is oriented so that the current direction is 50^0 S of W. The Earth's magnetic field is due north at this point and has a strength of $0.14 \times 10^{-4}T$. What is the size of the force on the wire?

(a) $0.28 \times 10^{-4}N$

(b) $2.5 \times 10^{-4}N$

(c) $1.9 \times 10^{-4}N$

(d) $1.6 \times 10^{-4}N$

16. A circular current loop is placed in an external magnetic field. How is the torque related to the radius of the loop?

(a) **directly proportional to radius**

(b) **inversely proportional to radius**

(c) **directly proportional to radius squared**

(d) **inversely proportional to radius squared**

17. A circular loop carrying a current of 1.0 A is oriented in a magnetic field of 0.35 T. The loop has an area of $0.24m^2$ and is mounted on an axis, perpendicular to the magnetic field, which allows the loop to rotate. If the plane of the loop is oriented parallel to the field, what torque is created by the interaction of the loop current and the field?

(a) $5.8N \cdot m$

(b) $0.68N \cdot m$

(c) $0.084N \cdot m$

(d) $0.017N \cdot m$

18. A circular loop carrying a current of 1.0 A is oriented in a magnetic field of 0.35 T. The loop has an area of $0.24m^2$ and is mounted on an axis, perpendicular to the magnetic field, which allows the loop to rotate. What is the torque on the loop when its plane is oriented at a 25^0 angle to the field?

(a) $4.6N \cdot m$

(b) $0.076N \cdot m$

(c) $0.051N \cdot m$

(d) $0.010N \cdot m$

19. A circular coil (radius = 0.40 m) has 160 turns and is in a uniform magnetic field. If the orientation of the coil is varied through all possible positions, the maximum torque on the coil by magnetic forces is $0.16N \cdot m$ when the current in the coil is 4.0 mA. What is the magnitude of the magnetic field?

(a) $0.37T$

(b) $1.6T$

(c) $0.50T$

(d) $1.2T$

20. When a magnetic field causes a charged particle to move in a circular path, the only quantity listed below which the magnetic force changes significantly as the particle goes around in a circle is the particle's:———

(a) energy.

(b) momentum.

(c) radius for the circle.

(d) time to go around the circle once.

21. A 100-m-long wire carrying a current of 4.0 A will be accompanied by a magnetic field of what strength at a distance of 0.050 m from the wire? $(magnetic permeability in empty space \mu_0 = 4\pi \times 10^{-7} T \cdot m/A)$

(a) $4.0 \times 10^{-5} T$

(b) $2.0 \times 10^{-5} T$

(c) $1.6 \times 10^{-5} T$

(d) 0

22. The current in a long wire creates a magnetic field in the region around the wire. How is the strength of the field at distance r from the wire center related to the magnitude of the field?

(a) field directly proportional to r

(b) field inversely proportional to r

(c) field directly proportional to r^2

(d) field inversely proportional to r^2

23. A high-voltage power line 20 m above the ground carries a current of 2000 A. What is the magnetic field due to the current directly underneath the power line? $(\mu_0 = 4\pi 10^{-7} T \cdot m/A)$

(a) $20\mu T$

(b) $35\mu T$

(c) $14mT$

(d) $0.30T$

24. A solenoid with 500 turns, 0.10 m long, carrying a current of 4.0 A and with a radius of 10^{-2} m will have what strength magnetic field at its center? (magnetic permeability in empty space $\mu_0 = 4\pi \times 10^{-7} T \cdot m/A$)

(a) $31 \times 10^{-4} T$

(b) $62 \times 10^{-4} T$

(c) $125 \times 10^{4} T$

(d) $250 \times 10^{-4} T$

25. A current in a solenoid coil creates a magnetic field inside that coil. The field strength is directly proportional to: ———

(a) the coil area.

(b) the current.

(c) Both (a) and (b) are valid choices.

(d) None of the above choices are valid

26. A current in a solenoid with N turns creates a magnetic field at the center of that loop. The field strength is directly proportional to:———

(a) number of turns in the loop.

(b) current strength.

(c) Both choices (a) and (b) are valid.

(d) None of the above are valid

27. A superconducting solenoid is to be designed to generate a magnetic field of 5.00 T. If the solenoid winding has 1 000 turns/m, what is the required current? $(\mu_0 = 4\pi \times 10^{-7} T \cdot m/A)$

(a) $1000A$

(b) $1900A$

(c) $3980A$

(d) $5000A$

28. When an electromagnet has an iron core inserted, what happens to the strength of the magnet?

(a) It increases.

(b) It remains the same.

(c) It decreases.

(d) Since it depends on the metal used in the wires of the electromagnet, any of the above.

29. A uniform 4.5-T magnetic field passes perpendicularly through the plane of a wire loop $0.10m^2$ **in area. What flux passes through the loop?**

(a) $5.0T \cdot m^2$

(b) $0.45T \cdot m^2$

(c) $0.25T \cdot m^2$

(d) $0.135T \cdot m^2$

30. A uniform 4.5-T magnetic field passes through the plane of a wire loop $0.10m^2$ **in area. What flux passes through the loop when the direction of the 4.5-T field is at a** 30^0 **angle to the normal of the loop plane?**

(a) $5.0T \cdot m^2$

(b) $0.52T \cdot m^2$

(c) $0.39T \cdot m^2$

(d) $0.225T \cdot m^2$

31. A loop of area $0.250m^2$ is in a uniform 0.020 0-T magnetic field. If the flux through the loop is $3.83 \times 10^{-3}T \cdot m^2$, what angle does the normal to the plane of the loop make with the direction of the magnetic field?

(a) 40.0^0

(b) 50.0^0

(c) 37.5^0

(d) **This is not possible.**

32. The units T·m2/s are equivalent to: ———

(a) $W.$

(b) $V.$

(c) $N/m.$

(d) $webers.$

33. According to Lenz's law the direction of an induced current in a conductor will be that which tends to produce which of the following effects?

(a) enhance the effect which produces it

(b) produce a greater heating effect

(c) produce the greatest voltage

(d) oppose the effect which produces it

34. The principle or law that says "an induced emf in a circuit loop produces a current whose magnetic field opposes further change of magnetic flux" is credited to:———

(a) Faraday.

(b) Lenz.

(c) Ampere.

(d) Volta.

35. A planar loop consisting of four turns of wire, each of which encloses $200cm^2$, is oriented perpendicularly to a magnetic field that increases uniformly in magnitude from 10 mT to 25 mT in a time of 5.0 ms. What is the resulting induced current in the coil if the resistance of the coil is 5.0Ω?

(a) $60mA$

(b) $12mA$

(c) $0.24mA$

(d) $48mA$

36. If the induced current in a wire loop were such that the flux it produces were in the same direction as the change in external flux causing the current, which of the following conservation laws would end up being violated?

(a) momentum

(b) charge

(c) energy

(d) angular momentum

37. A 0.200-m wire is moved parallel to a 0.500-T magnetic field at a speed of 1.50 m/s. What emf is induced across the ends of the wire?

(a) $2.25V$

(b) $1.00V$

(c) $0.600V$

(d) 0

38. The magnet moving past an object will produce eddy currents in the object if the object:———

(a) is magnetic material only.

(b) is a conductor.

(c) is an insulator.

(d) is a liquid.

39. The basic function of the electric generator is which of the following conversion processes?

(a) mechanical energy to electrical

(b) electrical energy to mechanical

(c) low voltage to high or vice versa

(d) angular momentum

40.The current in a coil with a self-inductance of 1.5 mH increases from 0 to 1.0 A in a tenth of a second. What is the induced emf in the coil?

(a) $15mV$

(b) $30mV$

(c) $0.10V$

(d) $0.30V$

41. A coil with a self-inductance of 0.75 mH experiences a constant current buildup from zero to 10 A in 0.25 s. What is the induced emf during this interval?

(a) $0.045V$

(b) $0.030V$

(c) $0.47V$

(d) $0.019V$

42. What is the self-inductance in a coil that experiences a 3.0-V induced emf when the current is changing at a rate of 110 A/s?

(a) $83mH$

(b) $45mH$

(c) $37mH$

(d) $27mH$

43. By what factor is the self-inductance of an air solenoid changed if only its number of coil turns, N, is tripled?

(a) $1/3$

(b) 3

(c) 6

(d) 9

44. By what factor is the self-inductance of an air solenoid changed if only its cross-sectional area, A, is tripled?

(a) $1/3$

(b) 3

(c) 6

(d) 9

45. The unit of inductance, the henry, is equivalent to:———

(a) $V \cdot s/A$.

(b) V/m.

(c) J/C.

(d) **none of the units given.**

Answer Sheet

I. Multiple Choice

C	2. B	3. A	4. B	5. D
6.C	7.C	8.B	9.D	10.C
11.C	12.C	13.C	14.A	15.D
16.C	17.C	18.C	19.C	20.C
21.C	22.B	23.A	24.D	25.B
26.C	27.C	28.A	29.B	30.C
31.A	32.B	33.D	34.B	35.D
36.C	37.D	38.B	39.A	40.A
41.B	42.D	43.D	44.B	45.A

Chapter 10

Introduction to Electronics

- **Electronics is the study and design of systems that use the flow of electrons throgh such components as semiconductors, resistors and capacitors.**
- **Electronics is a vital part of our daily life. At present, we can see have lots of electrical appliances in our home for daily activities and to make life comfortable.**

10.1 Vacuum Tube Devices

- **Vacuum Tube is an electronic device that controls the flow of electrons in a vacuum.**
- **The components of vacuume tube are the anode, cathode and the heater filament.**
- **Vacuum tube diodes contain only two electrodes (besides the heater); i.e.a cathode and an anode.**
- **Thermionic Emission is the escape of conduction electrons from a hot metal surface.**
- **Thermionic Emission may be accelerated through a high voltage to produce a beam of cathode rays.**
- **These cathode rays convey negative charge, and may be deflected accordingly by magnetic and electric fields.**
- **Cathode Ray Oscilloscope is electronic test equipment that provides visual images of electrical signals and oscillations.**
- **Diode is an electrical component with two electrodes, used for rectification.**

- **Rectification is converting alternating current to direct current.**
- **Electron Gun is an electrical component producing a beam of electronics moving through a vacuum at high speed.**
- **X-ray tube machine is also a vacuum tube device.**
- **Direct Current (d.c.) is an electric current that flows in a constant direction.**
- **Gain Control is a device adjusting the amount of beam deflection in a cathode ray oscilloscope.**
- **Sine Wave is a mathematical function that describes a smooth repetitive oscillation.**

10.2 Conductors, Semiconductors and Insulators

- **Semiconductor is a material with an electrical resistivity that is intermediate between the resistivities of good conductors and those of good insulators.**
- **Intrinsic Semiconductor is a pure semeconductor not containing any dopant.**
- **Hole is the lack of an electron at a position where one could exist in an atomic lattice.**
- **Intrinsic Conduction is electrons and holes in a semiconductor moving in opposite directions when an e.m.f. is applied.**
- **In a pure semiconductor, holes and electrons are always present in equal numbers.**
- **While the resistance of metallic conductors rises as they warm up, with semiconductors the resistance falls greatly as their temperature goes up.**
- **When the temperature of a semiconductor is raised, more electrons (charge carriers) have enough energy to break free.**
- **As the number of charge carriers increases, the resistance of the semiconductor materials decreases and the material conducts better.**

10.3 Semiconductors (Impurities, Doping)

- **Doping** is deliberately introducing impurities into a semiconductor to change its electrical properties.
- **Extrinsic Semiconductor** is a semiconductor that has been doped.
- **Majority Carriers** is the type of carriers, electron or hole, that constitutes more than half the carriers in a semiconductor.
- **n-type semiconductor** is a semiconductor in which the majority carriers are electrons, due to doping.
- **Minority Carriers** is the type of carrier, electron or hole, that constitutes less than half the carriers in a semiconductor.
- **p-type semiconductor** is a semiconductor in which the majority carriers are holes, due to doping.
- **Donor** is an impurity atoms added to a semiconductor which release free electrons.
- **Acceptor** is an impurity atoms added to a semiconductor which trap electrons.
- **Junction** is the region where two types of semiconducting materials touch.
- **p-n junction** is the boundary layer between two regions of a semiconductor, one with p-type impurities and the other with n-type impurities. This boundary region is called a **junction**; such a region can be fabricated by the deposition of n-type material on a clean surface of some p-type material, or in various other ways.
- **Reverse Biased** is connecting the positive terminal of a cell to the **n-type** region of a diode, and the negative terminal to the **p-type** region, preventing conduction.
- **Forward Biased** is connecting the positive terminal of a cell to **p-type region** of a diode, and the negative terminal to the **n-type region**, allowing conduction.
- **Some semiconductor devices** are: diode, light-dependent resistor (LDR),thermistor,variable resistor,light-emitting diode (LED), transistor,photodiode, photovoltaic cell.
- **A light-dependent resistor (LDR)** is conducts electricity, but in the dark it has a very high resistance.
- **Thermistor** is a piece of semiconductor materials that has high resistance in the

cold.Its resistance drops as it becomes warmer.

- **Variable resistor** is a very useful component in electronic circuits.
- **A light-emitting diode (LED)** is, as the name implies, a p-n junction that emits light.
- **Transistor** is a semiconductor device used to amplify or switch electronic signals.
- **Bipolar Junction Transistor** is a device in which the current flow between two terminals, the collector and emitter is controlled by the amount of current that flows through a third terminal, the base.
- **Photodiode** is a light sensitive diode used to detect light or to measure its intensity.
- **Photovoltaic Cell** is a cell that converts solar energy into electrical energy.
- **A semiconductor diode** can produce half-wave rectification from an alternating supply.
- **Bridge Rectifir** is an arrangement of four diodes which produce full-wave rectification of an alternating current.

10.4 Transistors (p-n-p, n-p-n)

- **Base** is one of the three regions forming a bipolar junction transistor. This layer separates the emitter and collector layers.
- **Collector** is one of the three regions forming a bipolar junction transistor.
- **Emitter** is one of the three regions forming a bipolar junction transistor.
- **n-p-n and p-n-p transistors**are bipolar junction transistors.
- **n-p-n Transistor** is the type of bipolar transistor consisting up of p-type semiconductor that is a fixed in between two n-type semiconductors.
- **p-n-p Transistor** is the type of bipolar transistor consisting up of n-type semiconductor that is a fixed in between two p-type semiconductors.
- **Two essential features of the transistor are:** The base layer has to be extremely thin; the collector must be arranged so as to be in physical contact with and surround as much of the base as possible.

- **Logic gates are an electronic device that performs a logical operation on two inputs and produces a single logic output.**
- **Logic gates is a device that acts as a building block for digital circuits. There are seven basic logic gates: AND, OR, XOR, NOT, NAND, NOR, and XNOR.**
- **AND gate is so named because, if 0 is called "false" and 1 is called "true", the gates acts in the same way as the logical "and" operator.**
- **In the circuit symbol for an AND gate, the inputs terminals are at the left and the output terminal is at the right. The output is "true" when both inputs are "true". Otherwise, the output is "false".**
- **OR gate its name from the fact that it behaves after the fashion of logical inclusive "or". The output is "true" if either or both of the inputs are "true". If both inputs are "false", then output is "false".**
- **XOR gate acts in the same way as the logical "either/or". The output is "true" if either, but not both, of the inputs are "true". The output is "false" if both inputs are "false" or both inputs are "true" Another way of looking at this circuit is to observe that the output is 1 if the inputs are different, but 0 if the inputs are the same.**
- **NOT gate is sometimes called logical inverter.**
- **NOT gate to differentiate it from other types of electronic inverter devices, has only one input. It reverses the logic state. If the inputs is 1, then the output is 0.if the inputs are 0, then the output is 1.**
- **NAND gate operates as AND gate followed by a NOT gate. It acts in the manner of the logical operation "and" followed by negation. The output is "false" if both inputs are "true". Otherwise, the output is "true".**
- **NOR gate is a combination OR gate followed by an inverter. Its output is "true" if both inputs are "false". Otherwise, the output is "false".**
- **XNOR (exclusive-NOR) gate is a combination of XOR gate followed by an inverter.Its output is "true" if the inputs are the same, and "false" if the inputs are**

different.

- T

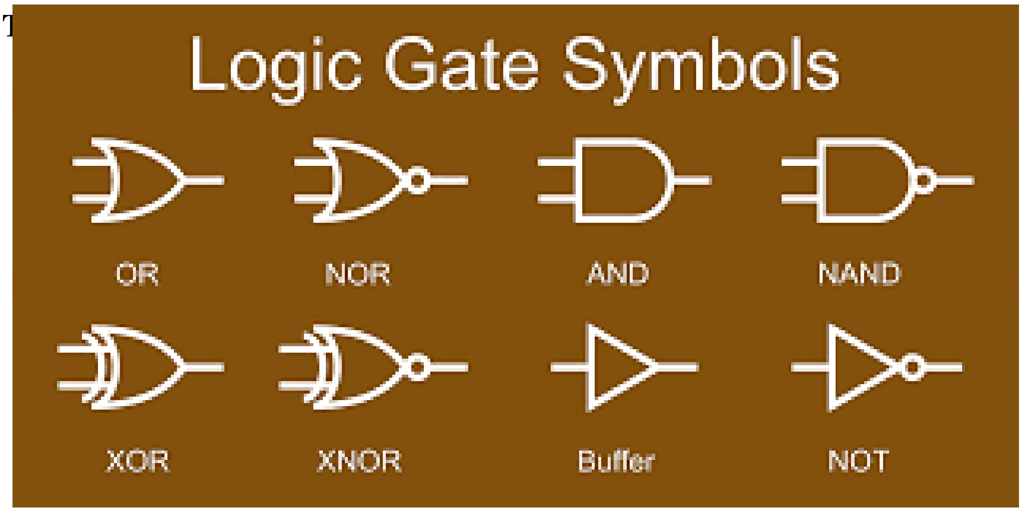


Fig. 10.1. Symbols of Logic Gates

Multiple Choice Questions

Choose the correct answer from the choice of each questions

1. Which of the following has the least number of valance electron———

(a) Conductor

(b) Semiconductor

(c) Insulator

(d) Semi-insulator

2. A good conductor has how many valence electrons?———

(a) 8

(b) 4

(c) 2

(d) 1

3.Which element has four valance electrons? ———

(a) Conductor

(b) Insulator

(c) Semiconductor

(d) Semi-insulator

4. The temperature coefficient of resistance of semiconductor is———

(a) Positive

(b) Negative

(c) zero

(d) Infinite

5.The temperature coefficient of resistance of a conductor ——— with an increase in temperature.

(a) increase

(b) decrease

(c) remains the same

(d) becomes negative

6. What is considered as the key electrical conductivity?———

(a) The number of electrons in the valance electron

(b) The number of protons in nucleus

(c) The number of neutrons in nucleus

(d) The number of protons plus the number of electrons in the atom

7. An extrinsic semiconductor is a———

(a) Doped semiconductor

(b) Pure semiconductor

(c) Good insulator

(d) Good conductor

8. Silicon that has been doped with a trivalent impurity is called a/an———

(a) n-type semiconductor

(b) p-type semiconductor

(c) intrinsic semiconductor

(d) extrinsic semiconductor

9. What is another name for a pn crystal———

(a) Diode

(b) PN junction

(c) Junction diode

(d) Lattice

10. In an n-type semiconductor, free electron are called———

(a) Minority carriers

(b) Valance electrons

(c) Majority carriers

(d) Charge carriers

11. In an n-type semiconductor, holes are called———

(a) minority carriers

(b) majority carriers

(c) protons

(d) charge carriers

12. The creation of free electrons through zener effect is also known as———

(a) **Avalanche emission**

(b) **Thermionic emission**

(c) **Low-field-emission**

(d) **High-field emission**

13. One of the important diode parameter which gives the magnitude of current the diode candle without burning.

(a) **Reverse saturation current**

(b) **Reverse current**

(c) **Forward Current**

(d) **Forward breakdown current**

14. A diode is a nonlinear device because———

(a) **It produces a nonlinear graph**

(b) **Its current is not directly proportional to its voltage**

(c) **It has a built-in barrier potential**

(d) **It can rectify alternating current**

15. The sum of the resistance of the p-region and n-region is called———

(a) **Junction resistance**

(b) **Extrinsic resistance**

(c) **Intrinsic resistance**

(d) **Bulk resistance**

16. The reverse bias diode capacitance is termed as———

(a) **Transition region capacitance**

(b) **Diffusion capacitance**

(c) Storage capacitance

(d) Reverse capacitance

17. The time taken by the diode to operate in the reversed condition from forward conduction———

(a) Maximum power time

(b) Reverse recovery time

(c) Lifetime

(d) Time allocation

18. When the emitter junction is forward biased while the collector junction is reverse biased, the transistor is at ———region.

(a) Cut-off

(b) Saturation

(c) Active

(d) Breakdown

19. When both emitter and collector junction are forward biased, the transistor is said to be at ———region.

(a) Active

(b) Cut-off

(c) Breakdown

(d) Saturation

20. With pnp voltage divider biaas, you must use

(a) Ground

(b) Negative power supplies

(c) Positive power supplies

(d) Resistors

21. When doping increases,———of a semiconductor decreases.

(a) Impurity

(b) Conductivity

(c) Bulk resistance

(d) Minority carrier

22. When both emitter and collector junction are reverse biased, the transistor is said to be at ———region.

(a) Active

(b) Cut-off

(c) Saturation

(d) Amplifying

23. What is the approximate voltage drops of LED?

(a) $0.3V$

(b) $0.7V$

(c) $1.5V$

(d) $3.8V$

24. As a general rule,——— are found only in semiconductors.

(a) Electrons

(b) Bulk resistances

(c) Deplation layers

(d) Holes

25. When the number of free electrons is increased in doped semiconductor, it becomes a/an——— semiconductor.

(a) n-type

(b) p-type

(c) pn type

(d) np type

26. A———is considered a current controlled device

(a) Diode

(b) Field effect transistor

(c) Transistor

(d) Resistor

27. If the temperature of a semiconductor material increases, the number of free electrons

(a) Decrease

(b) Increase

(c) Remains the same

(d) Becomes zero

28. In an amplifier, the emitter junction is———

(a) Forward biased

(b) Reverse biased

(c) Grounded

(d) Shorted

29. The——— transistor configuration has the highest value of input resistance.

(a) Common base

(b) Common emitter

(c) Emitter-stablized

(d) Common collector

30. What is the largest region of a bipolar transistor?

(a) Base

(b) Emitter

(c) Collector

(d) P-region

31. What are the majority current carriers in the N-type silicon?

(a) Free electrons

(b) Holes

(c) Bounded electrons

(d) Protons

32. A transistor has———

(a) one pn junction

(b) two pn junctions

(c) three pn junctions

(d) four pn junctions

33. The number of depletion layers in a transistor is———

(a) four

(b) three

(c) one

(d) two

34. The element that has the biggest size in a transistor is ———

(a) collector

(b) base

(c) emitter

(d) collector-base-junction

35. The part of a transistor which is heavily doped to produce a large number of majority carriers, is———

(a) Base

(b) Emitter

(c) Collector

(d) None of these

36. In p-n-p transistor will be of———

(a) p-terminal

(b) n-terminal

(c) Either of the above

(d) None of the above

37. Which logic gate is included in a binary adder circuit to enable binary addition and subtraction?

(a) Ex-OR Gate

(b) AND Gate

(c) Ex- AND Gate

(d) OR Gate

38. Which gate is also an inverter gate?

(a) NAND

(b) NOT

(c) AND

(d) OR

39.———gate represent multiplication operation.

(a) NAND

(b) NOT

(c) AND

(d) OR

40. ——— gate represents the complement of the input.

(a) NAND

(b) NOT

(c) AND

(d) OR

41. Which of the following logical operation has '+' as its symbol——-

(a) NAND

(b) NOT

(c) AND

(d) OR

42. Which of the following gates are interchangeable?

(a) NAND and NOR

(b) NOR and OR

(c) AND and OR

(d) NOR and bubbled OR

43. If one of the inputs of the 2-input logic gate is LOW, then which of the following gate still has a HIGH output is HIGH?

(a) AND

(b) NAND

(c) NOR

(d) OR

Answer Sheet

I. Multiple Choice

1.A	2. D	3. C	4. B	5. B
6. A	7. A	8. 8	9. C	10. C
11. A	12. D	13. C	14. B	15. D
16. A	17. B	18. C	19. D	20. B
21. C	22. B	23. C	24. D	25. A
26. C	27. B	28. A	29. D	30. C
31. A	32. B	33. D	34. A	35. B
36. B	37. A	38. D	39. C	40. B
41. D	42. A	43. B		

Chapter 11

Electromagnetic Waves and Geometrical Optics

11.1 Electromagnetic Waves

- **There are two types of wave; transverse and longitudinal.**
- **Transverse wave is a traveling wave or pulse that causes the elements of the disturbed medium to move perpendicular to the direction of propagation.**
- **Example:** Light wave, water wave.
- **Longitudinal wave is a traveling wave or pulse that causes the elements of the medium to move parallel to the direction of propagation**
- **Example:** Sound wave.
- **Electromagnetic waves are produeced when manetic and an electric field are at right angles to each other. Electromagnetic waves are transverse waves. Electromagnetic waes do not need a medium through which travel- they can travel through a vacuum.**
- **Amplitude is the maximum distance of a wave moves above or below the base line.**
- **Frequency is the number of complate waves passing a given point in a second.**
- **Wavelength is the distance between successive peaks or troughs on a wave.**
- **Speed is the distance traveled per unit time.**

- **The frequency, wavelength and speed of a wave are related by the formula:**

$$v = f\lambda \tag{11.1}$$

- **Electromagnetic waves cover an extremely broad spectrum of wavelengths and frequencies.**
- **Radio and TV transmission, visible light, infrared and ultraviolet radiation, x rays, and gamma rays all form parts of the electromagnetic spectrum.**
- **Visible light is the most important part of electromagnetic spectrum to everyday life.**
- **The various wavelengths of visible light, which correspond to different colors, range from red** $(\lambda \approx 7 \times 10^{-7} m)$ **to violet** $(\lambda \approx 4 \times 10^{-7} m)$**.**
- **The sensitivity of the human eye is a function of wavelength,being a maximum at a wavelength of about** $5.5 \times 10^{-7} m$**.**
- **X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.**
- **X-rays have wavelength in range from approximately** $10^{-8} to 10^{-12} m$
- **Infrared waves have wavelengths ranging from approximately** $10^{-3} m$ **to the longest wavelength of visible light,** $7 \times 10^{-7} m$**.**
- **Infrared radiation has practical and scientific applications in many areas, including physical therapy, IR photography, and vibrational spectroscopy.**
- **Microwaves have wavelengths ranging from approximately 0.3 m to** $10^{-4} m$ **and are also generated by electronic devices.**
- **Radio waves, whose wavelengths range from more than** $10^{4} m$ **to about 0.1 m, are the result of charges accelerating through conducting wires.**
- **Radio waves are used in radio and television communication systems.**

11.2 Reflection of Light

- **When a beam of light strikes such an interface, some light is always scattered backward, and we call this phenomenon reflection.**
- **The direction of a reflected ray is in the plane perpendicular to the reflecting surface that contains the incident ray.**
- **Reflection of light from such a smooth surface is called specular reflection.**
- **Reflection from any rough surface is known as diffuse reflection.**
- **The first law of reflection is straightforward: The angle of reflection is equal to the angle of incidence.**
- **The reflected ray lies in the plane which contains the incident ray and normal.**
- **A plane mirror produces an image that is the same size as the object.**
- **Using the laws of reflection to explain how images are formed in a plane mirror and using a ray tracing method to find the position of the image.**

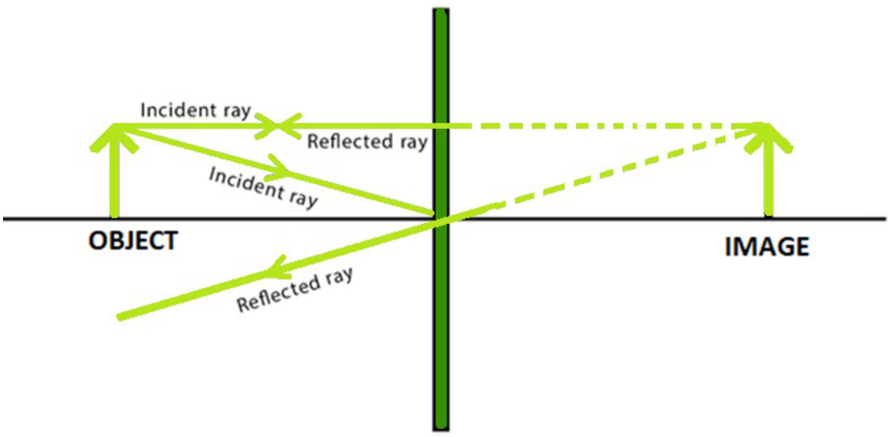


Fig. 11.1. Plane Mirror

- **Concave mirror reflect light inward to one focal light. Therefore, they are mostly used to focus light. A concave mirror shows different image types depending on the distance between the mirror and the object.**
- **Convex mirror is a mirror with a reflecting surface that bulges outwards, towards the light source. It is sometimes called a diverging mirror.**
- **The figure below shows the position an nature of the image formed by a convex**

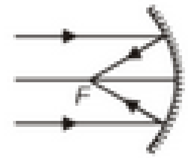
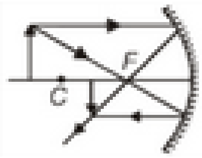
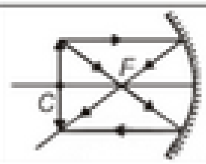
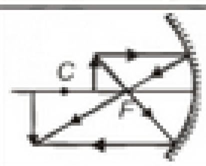
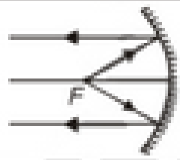
Position of object	Figure	Position of image	Nature of image
1. At infinity		At the principal focus or in the focal plane	Real, inverted, extremely diminished in size
2. Beyond the centre of curvature		Between the principal focus and centre of curvature	Real, inverted and diminished
3. At the centre of curvature		At the centre of curvature	Real, inverted and equal to object
4. Between focus and centre of curvature		Beyond centre of curvature	Real, inverted and bigger than object.
5. At the principal focus		At infinity	Extremely magnified
6. Between the pole and principal focus		Behind the mirror	Virtual, erect and magnified

Fig. 11.2. Image formation in Concave Mirror

mirror using mirror equation and a ray tracing method

- **Terms used in concave and convex mirrors:**
- **Magnification is the ratio between the height of an image and the height of the object. The magnification is given by:**

$$Magnification = \frac{height\ image}{height\ object} \quad (11.2)$$

- **Principal axis is the line passing through the optical vertex and center of curvature**

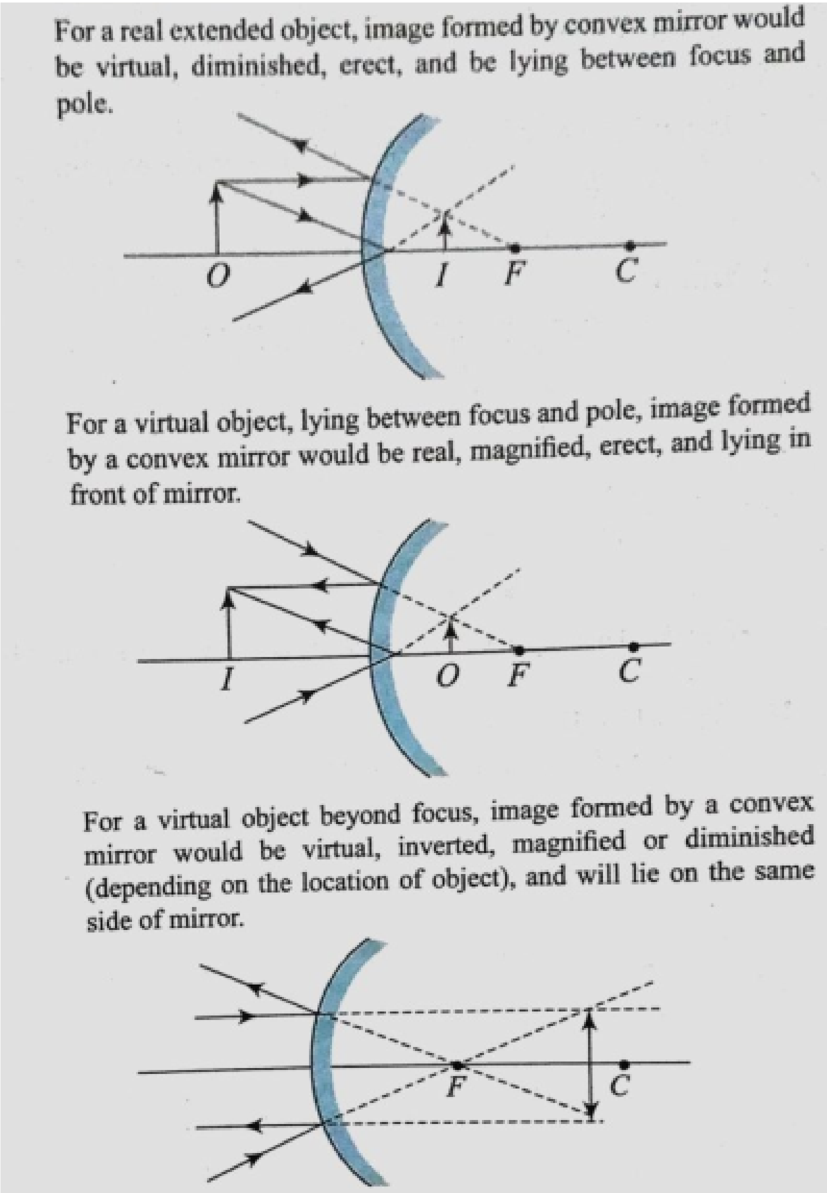


Fig. 11.3. Image formation in Convex Mirror

of the face of a curved mirror.

- **Principal focus is the point at which all light reflecting from a curved mirror converges.**
- **Radius of curvature is the radius of the sphere that forms the basic curve of a concave mirror.**
- **Real image is an image that can be captured on a screen.**
- **Virtual image is an image that cannot be captured on a screen.**

11.3 Refraction of Light

- **Refraction is the change in direction of travel of a light beam as the light crosses the boundary between one transparent medium and another.**
- **The index of refraction of an optical material (also called the refractive index), denoted by n, plays a central role in geometric optics.**
- **It is the ratio of the speed of light c in vacuum to the speed v in the material:**

$$n = \frac{c}{v} \qquad (index\ of\ refraction) \tag{11.3}$$

- **Light always travels more slowly in a material than in vacuum, so the value of n in anything other than vacuum is always greater than unity. For vacuum, n = 1.**
- **The Laws of Reflection and Refraction:**
- **The incident, reflected, and refracted rays and the normal to the surface all lie in the same plane.**
- **The plane of the three rays and the normal, called the plane of incidence, is perpendicular to the plane of the boundary surface between the two materials.**
- **The angle of reflection θ_r is equal to the angle of incidence θ_i for all wavelengths and for any pair of materials.**

$$\theta_r = \theta_i \qquad (law\ of\ reflection) \tag{11.4}$$

- **This relationship, together with the observation that the incident and reflected rays and the normal all lie in the same plane, is called the law of reflection.**
- **The angle of reflection is equal to the angle of incidence, and the angle of refraction is related to the angle of incidence by Snell's law,**

$$n_2 sin\theta_2 = n_1 sin\theta_1 \qquad (refraction). \tag{11.5}$$

where n_1 and n_2 are the indexes of refraction of the media in which the incident and refracted rays travel.

- **Lateral Displacement** is the perpendicular distance between the pathway of the incident light ray and the one that emerges after refraction from two surfaces of a medium.
- **Total Internal Reflection:** A wave encountering a boundary across which the index of refraction decreases will experience **total internal reflection** if the angle of incidence exceeds a **critical angle** θ_c, where

$$\theta_c = sin^{-1}\frac{n_2}{n_1} \qquad (critical\ angle). \tag{11.6}$$

- **Total internal reflection** occurs when light strikes a medium boundary at an angle of incidence greater than the critical angle, and all light is reflected.
- **Total internal reflection** is used in optical fibers because the light is trapped within the cable.
- **Critical angle** is the angle of incidence on a boundary above with the total internal reflection occurs.
- **Fiber optics** is a glass or plastic fibers that carry light along their length.
- **Convex lens** is a converging lens which works much like a concave mirror. This kind of lens is thicker in the middle and thinner towards the edges, like the lens in a magnifying glass.
- **A concave lens** is a diverging lens which works similar to the convex mirror. This lens is thicker towards the edges and thin in the middle and are used in helping correction of nearsightedness.
- **Dioptre** is a unit of measurement of the optical power of a lens or curved mirror.
- The position and nature of an image formed by a convex lens are as shown below:
- **Accommodation** is the eye's ability to focus on objects at various image.
- **The near point** is the closest distance for which the lens can accommodate to focus light on the retina.

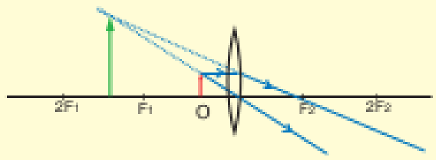
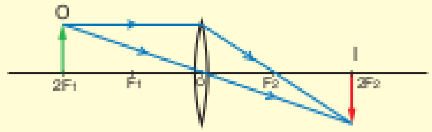
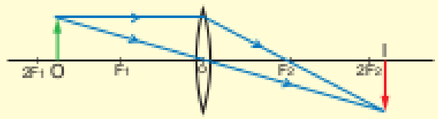
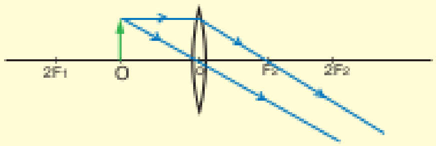
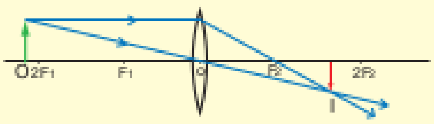
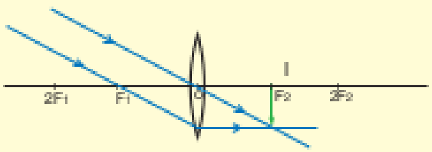
Position of object	Key diagram	Image is
Between F_1 and lens		virtual erect magnified
At $2F_1$		real inverted same size as object
Between F_1 and $2F_1$		real inverted magnified
At F_1		formed at infinity real inverted magnified
Beyond $2F_1$		formed between F_1 and $2F_1$ real inverted diminished
At infinity		formed at F_1 inverted real highly diminished

Fig. 11.4. Image formation in Convex Lens using a ray tracing method

- **The far point of the eye represents the greatest distance for which the lens of the relaxed eye can focus light on the retina.**
- **A farsighted person (or hyperopia) can usually see faraway objects clearly but not nearby objects.**

- **A person with nearsightedness (or myopia), another mismatch condition, can focus on nearby objects but not on faraway objects.**
- **In eyes having a defect known as**
- **astigmatism, light from a point source produces a line image on the retina.**
- **This condition arises when the cornea, the lens, or both are not perfectly symmetric.**
- **Astigmatism can be corrected with lenses that have different curvatures in two mutually perpendicular directions.**
- **The simple magnifier, or magnifying glass, consists of a single converging lens. This device increases the apparent size of an object.**
- **The position and nature of the image formed by a convex and concave lens can be found using the thin lens formula and a ray tracing method.**
- **The Power of a lens is defined by:**

$$power\ of\ a\ lens = \frac{1}{its\ focal\ length\ in\ meters} \tag{11.7}$$

- **Diffraction is the change of direction of a wave at the edge of an obstacle in its path.**
- **Diffraction grating is a material with a large number of narrow, regularly spaced slits, designed to produce a diffraction pattern.**
- **Greater magnification can be achieved by combining two lenses in a device called a compound microscope.**
- **A telescope is designed for sensing more detail in an object that is a long distance away.**
- **Telescopes are designed to aid in viewing distant objects such as the planets in our solar system.**
- **Two fundamentally different types of telescopes exist; these are refracting telescope, and reflecting telescope.**

Multiple Choice Questions

Choose the correct answer from the choice of each questions

1. A ray of light strikes a thick sheet of glass (n = 1.5) at an angle of 25^0 with the normal. Find the angle of the ray reflected off the glass surface with respect to the normal.———

(a) 56^0

(b) 46^0

(c) 39^0

(d) 25^0

2. When light reflects and produces a clear image, this reflection is referred to as:———

(a) **specular reflection.**

(b) **diffuse reflection.**

(c) **retroreflection.**

(d) **double reflection.**

3. A ray of light strikes a thick sheet of glass (n = 1.5) at an angle of 25^0 with the normal. Find the angle of the refracted ray within the glass respect to the normal.———

(a) 56^0

(b) 46^0

(c) 25^0

(d) 16^0

4. What is the angle of incidence on an air-to-glass boundary if the angle of refraction in the glass (n =1.52) is 25^0?

(a) 16^0

(b) 25^0

(c) 40^0

(d) 43^0

5. A beam of monochromatic light goes from material 1 with index of refraction n_1 into material 2 with index of refraction n_2. The frequency of light in material 1 is f_1 and in material 2 is f_2. What is the ratio of f_1/f_2?

(a) n_1/n_2

(b) n_2/n_1

(c) 1

(d) The values of n_1 and n_2 must be known to find the answer.

6. The lowest possible value for the index of refraction is:——

(a) 0

(b) 1

(c) 0.707

(d) $3^{1/2}$

7. A light-sensitive cells lining the inner surface of the eye is:——

(a) optic nerve

(b) retina

(c) pupil

(d) iris

8. When light passing through a prism undergoes dispersion, the effect is a result of:

(a) different wavelengths traveling at different speeds.

(b) different wavelengths having different indices of refraction.

(c) different wavelengths refracting differently.

(d) All of the above.

9. Which of the following describes what will happen to a light ray incident on a glass-to-air boundary at greater than the critical angle?

(a) total reflection

(b) total transmission

(c) partial reflection, partial transmission

(d) partial reflection, total transmission

10. If total internal reflection occurs at a glass-air surface::——

(a) no light is refracted.

(b) no light is reflected.

(c) light is leaving the air and hitting the glass with an incident angle greater than the critical angle.

(d) light is leaving the air and hitting the glass with an incident angle less than the critical angle.

11. Before light can undergo total internal reflection when incident on material 2 from material 1, what must be true of the indices of refraction?——

(a) $n_1 = n_2$

(b) $n_1 < n_2$

(c) $n_1 > n_2$

(d) Either n_1 **or** n_2 **must be equal to 1.**

12.Which of the following best describes the image from a plane mirror?

(a) virtual and magnification greater than one

(b) real and magnification less than one

(c) virtual and magnification equal to one

(d) real and magnification equal to one.

13. When the reflection of an object is seen in a plane mirror, the image is:

(a) real and upright.

(b) real and inverted.

(c) virtual and upright.

(d) virtual and inverted.

14. When the reflection of an object is seen in a plane mirror, the distance from the mirror to the image depends on:——

(a) the wavelength of light used for viewing.

(b) the distance from the object to the mirror.

(c) the distance of both the observer and the object to the mirror.

(d) the size of the object.

15. How large should a wall-mounted mirror be to view the upper half of one's height,h?

(a) h

(b) $h/2$

(c) $h/4$

(d) The answer is not given.

16.The real image of an object is located 45.0 cm away from a concave mirror, which has a focal length of 10.0 cm. How far is the object from the mirror?

(a) 40.0cm

(b) 35.0cm

(c) 22.5cm

(d) 12.9cm

17. If a virtual image is formed along the principal axis 10 cm from a concave mirror with the focal length 15 cm, what is the object distance from the mirror?

(a) 30cm

(b) 10cm

(c) 12cm

(d) 6.0cm

18. If a virtual image is formed 10.0 cm along the principal axis from a convex mirror of focal length 15.0 cm, how far is the object from the mirror?

(a) 30.0cm

(b) 10.0cm

(c) 6.00cm

(d) 3.00cm

19. A woman looking in a makeup mirror sees her face at twice its actual size and right-side up. If she is 28.0 cm from the mirror, what is its focal length?

(a) 18.6cm

(b) 44.0cm

(c) 48.3cm

(d) 56.0cm

20. Which best describes the image of a concave mirror when the object is located somewhere between the focal point and twice the focal point distance from the mirror?

(a) virtual, upright and magnification greater than one

(b) real, inverted and magnification less than one

(c) virtual, upright and magnification less than one

(d) real, inverted and magnification greater than one

21. Which of the following best describes the image of a concave mirror when the object is at a distance greater than twice the focal point distance from the mirror?

(a) virtual, upright and magnification greater than one

(b) real, inverted and magnification less than one

(c) virtual, upright and magnification less than one

(d) real, inverted and magnification greater than one

22. A convex mirror with a focal length of -20 cm forms an image 15 cm behind the surface. If the object height is 1.2 cm what is the image height?

(a) 0.30cm

(b) 0.75cm

(c) 0.94cm

(d) 3.00cm

23. When the reflection of an object is seen in a concave mirror the image will:

(a) always be real.

(b) always be virtual.

(c) may be either real or virtual.

(d) will always be enlarged.

24. When the reflection of an object is seen in a convex mirror the image will:

(a) always be real.

(b) always be virtual.

(c) may be either real or virtual.

(d) will always be enlarged.

25. Parallel rays of light that hit a concave mirror will come together:

(a) at the center of curvature.

(b) at the focal point.

(c) at a point half way to the focal point.

(d) at infinity.

26. A girl is standing in front of a concave mirror. Consider two rays of light, one from her nose and one from her mouth that are parallel as they are traveling toward the mirror. These rays will come together:

(a) at the focal point.

(b) at the center of curvature.

(c) at the image point.

(d) behind the mirror if she is too close to the mirror.

27. An object 2 cm high is placed 10 cm in front of a mirror. What type of mirror and what radius of curvature is needed for an image that is upright and 4 cm tall?

(a) Concave, R = 20 cm

(b) Concave, R = 40 cm

(c) Convex, R = -10 cm

(d) Convex, R = -20 cm enlarged.

28. An object is placed 10 cm in front of a mirror, and an image is formed that has a magnification of 2. Which of the following statements is true?

(a) The focal length of the mirror is 30 cm.

(b) The image is real.

(c) There is not enough information to select the correct answer.

(d) This is the only true statement.

29. Which of the following best describes the image for a thin convex lens that forms whenever the object is at a distance less than one focal length from the lens?

(a) inverted, enlarged and real

(b) upright, enlarged and virtual

(c) upright, diminished and virtual

(d) inverted, diminished and real

30. Which of the following best describes the image for a thin concave lens that forms whenever the magnitude of the object distance is less than that of the lens' focal length?

(a) inverted, enlarged and real

(b) upright, enlarged and virtual

(c) upright, diminished and virtual

(d) inverted, diminished and real

31. Ansel places an object 30 cm from a thin convex lens along the axis. If a real image forms at a distance of 10 cm from the lens, what is the focal length of the lens?

(a) 30 cm

(b) 15 cm

(c) 10 cm

(d) 7.5 cm

32. An object is placed at a distance of 50 cm from a thin lens along the axis. If a real image forms at a distance of 40 cm from the lens, on the opposite side from the object, what is the focal length of the lens?

(a) 22 cm

(b) 45 cm

(c) 90 cm

(d) 200 cm

33. Ellen places an object 40.0 cm from a concave lens. If a virtual image appears 10.0 cm from the lens on the same side as the object, what is the focal length of the lens?

(a) -50.0 cm

(b) -13.3 cm

(c) -10.0 cm

(d) -8.00 cm

34. When an image is inverted compared to the object, it is also:

(a) virtual.

(b) reversed left to right.

(c) enlarged.

(d) diminished.

35. What is the image distance of an object 1.00 m in front of a converging lens of focal length 20.0 cm?

(a) +16.7 cm

(b) +20.0 cm

(c) +25.0 cm

(d) +33.3 cm

36. An object and a screen are separated by 20.00 cm. A convex lens is placed between them, 5.00 cm from the object. In this position it causes a sharp image of the object to form on the screen. What is the focal length of the lens?

(a) 15.0 cm

(b) 5.00 cm

(c) 3.75 cm

(d) 2.00 cm

37. An object, located 90 cm from a concave lens, forms an image 60 cm from the lens on the same side as the object. What is the focal length of the lens?

(a) -36.0 cm

(b) -75.0 cm

(c) -180.0 cm

(d) -150.0 cm

38. A 100-cm focal length thin lens is placed in contact with one of 66.7 cm focal length. A 3.0 cm tall object is placed 50 cm in front of the combination. What is the size of the image?

(a) 3.8 cm

(b) 1.9 cm

(c) 4.0 cm

(d) 12.0 cm

39. Three thin lenses, each of focal length f, are placed in contact. What is the resulting focal length of the combination?

(a) f

(b) 3f

(c) f/3

(d) 3/f

40. When you stand in front of a plane mirror, your image is:

(a) real, erect, and smaller than you

(b) real, erect, and the same size as you

(c) virtual, erect, and smaller than you

(d) virtual, erect, and the same size as you

41. A converging lens will be prescribed by the eye doctor to correct which of the following?

(a) farsightedness

(b) glaucoma

(c) nearsightedness

(d) astigmatism

42.The ciliary muscle is instrumental in changing the shape of which eye part?

(a) iris

(b) lens

(c) pupil

(d) retina

43. Which term below identifies the eye defect characterized by an inability to see distant objects clearly?

(a) myopia

(b) presbyopia

(c) hyperopia

(d) astigmatism

44. While a camera has film where the image is formed, the eye forms the image on the:

(a) pupil.

(b) cornea.

(c) retina.

(d) optic nerve

45. Glaucoma occurs because:

(a) the eye cannot accommodate properly.

(b) there is too much pressure in the fluid in the eyeball.

(c) the shape or size of the eye is not normal.

(d) the lens is partially or totally opaque.

46. Two thin lenses have powers P_1 and P_2, measured in diopters. If these lenses are placed in contact with one another, the resulting power is:

(a) more than both P_1 and P_2.

(b) less than both P_1 and P_2.

(c) half-way between P_1 and P_2.

(d) $P_1 + P_2$.

47. A thin lens of focal length 20 cm is placed in contact with a 20-diopter thin lens. What is the power of the combined lenses?

(a) 1/2 diopter

(b) 15 diopters

(c) 25 diopters

(d) 40 diopters

48. A magnifying lens with a focal length of 10 cm has what maximum magnification? (Assume the near point is 25 cm).

(a) 1.4

(b) 2.5

(c) 11

(d) 3.5

49. A magnifying lens with a focal length of 20 cm has what magnification when the viewing eye is relaxed?

(a) 7.14

(b) 1.3

(c) 1.8

(d) 2.3

50. Doubling the focal length of the objective lens of a compound microscope will change the magnification by what factor?

(a) 1/4

(b) 1/2

(c) 2

(d) 4

Answer Sheet

I. Multiple Choice

1.D	2. A	3. D	4. C	5. C
6. B	7. B	8. D	9. A	10. A
11. C	12. C	13. C	14. B	15. C
16. D	17. D	18. A	19. D	20. D
21. B	22. A	23. C	24. B	25. B
26. A	27. B	28. D	29. B	30. C
31. D	32. A	33. B	34. B	35. C
36. C	37. C	38. D	39. C	40. D
41.C	42. B	43. A	44. C	45. B
46. D	47. C	48. D	49. B	50. B

Chapter 12

Measurement

12.1 Science of measurement

- **A science of measurement is used to reduce uncertainty in measurement, to increase the precision of measurement, and to certify the quality of a material.**
- **Scientific method is a systematic process through observation, reasoning, modeling, and theoretical prediction.**
- **Significant figures are the number of digits used in a measurement regardless of the location of the decimal point.**
- **The rules of significant figures are;**
  - **a) All non - zero digits in a number are significant. Example: 1426 has four significant fugues**
  - **b) All zeros between two non-zero digits are significant .Example: 4007 has four significant figures**
  - **c) Zeros used to show the decimal point before non-zero digit is not significant. Example 0.000425 has three significant figures**
  - **d) Zeros at the end without the decimal point (trial zeros) are not significant .**
- **The techniques of rounding off significant figure during calculation are;**

–

- **1) Number greater than 5 can be round off to the preceding digit as 1**
- **2) Number less than 5 can be round off to the preceding digit as 0**
- **3) Number 5 can round off to the preceding digit as 1 if the preceding digit is odd and as 0 if the preceding digit is even.**

12.1 .1 Errors in measurement

- **Uncertainty is the amount of doubt in a measurement but it doesn't mean wrong, and error in a measurement is the uncertainty in a measurement but it does not mean mistake. Error = | true value - measured value|**
- **The two types of error are random error and systematic error,**
- **Random error is unpredictable that has no pattern and it occurs by chance and it may be above and below to the true value of a measurement .it can be reduce by taking the average of all repeated measurement.**
- **Systematic error is error that has bias (pattern) in a measurement and, it may be all above or all remain below the true value. It can be reduced by identifying the source of error.**
- **The sources of error in a measurement are personal error, zeros (instrumental) error, and parallax error.**

12.1 .2 precision, accuracy, and significant figure

Accuracy is the degrees of closeness to the true (accepted) value of a measurement .it is the degree of correctness or how close a measurement to the true value. Precision is the degree of strict exactness of a measurement .it is the degree to which repeated measurement under the same condition gives the same value or it is how close measurement of the same item are each other .

- **The significance of a measurement is indicated by the number of significant digits, and it determines the precision of a measurement.**
- **As the significant figures of a measurement increases then the precision of a measurement also increases.**
- **The precision of an instrument depends on the smallest scale division of the instrument.**
- **Accuracy measurement can be a precise measurement but precise measurement cannot be accurate measurement.**

Multiple Choice Questions

1) **Which one of the following statement is not true?**

   A) Error never be avoided

   B) Random error has pattern

   C) Systematic error has pattern

   D) Random error can be reduced by taking the mean of repeated measurement

   Answer: B, random error has no pattern, it occurs randomly

2) **How many significant digits the number 0.001022 have?**

   A) Two B) four C) six D) seven

   Answer: B, since 0.001022 has four significant digits

3) **Which one is the source of experimental error?**

   A) Personal error B) parallax error C) zeros error D) all of the above.

   Answer: D, all are the sources of error

4) **Which one of the following statement is true?**

   A) Random error affects the precision of a measurement.

B) Systematic error affects the precision of a measurement.

C) Zeros error is a systematic error

D) all of the above.

Answer: D, all statements are true.

5) **Which one is the correct rounding off 2.3451 to three significant digits?**

A) 2.34 B) 2.35 C) 2.345 D) 0.345

Answer: A 2.3451=2.34, since the number before 5 is even (4) therefore 5 cannot round off.

6) **A student measure the voltage across the circuit if the current is measured to be 2.21A and the resistance is 0.4, what is the correct value of voltage?**

A) 0.9V B) 0.88V C) 0.8V D) 0.88V

Answer: A, since V=I .R =(2.21)x(0.4)=0.884 V is correctly written to the least significant digit i.e. two digit so V=0.9V

7) **A teacher measure the amount of electric current as $I = 2.2A0.1$, what is the percentage of error?**

A) 4.58% B) 5.4% B)4% D)5.8%

Answer: A, %error = (Error/T.V)x100=(0.1/2.2)x100=4.58%

Chapter 13

Vector Quantity

13.1 Types of vector

Physical quantity can be classified as basic and derived physical quantity. Basic (fundamental) physical quantities are mass, length, time, temperature, electric current, amount of substance, and luminous intensity, and basic -SI units are kilogram, meter, second, kelvin, Ampere, mole, candela.

- **Physical quantity can also classify as vector and scalar physical quantity.**
- **Vector physical quantity have both magnitude and direction, Examples: displacement, velocity, acceleration, force, momentum, impulse... it can be negative meaning in opposite direction.**
- **Scalar physical quantity have only magnitude (dimension),it can't be negative**
- **Vector can be represented by graphically and symbolically.**
- **Types of vector are position vector, unit vector, collinear vector, coplanar vector, orthogonal vector.**
- **A unit vector is a vector that has a magnitude of one unit, and it is used to show the direction of a given vector. Example : i , j ,k**

- **Collinear vectors are vectors that exist along the same line, and they may be parallel or opposite to each other.**

- **Coplanar vectors are vectors that act on the same plan, and they may be parallel, opposite or perpendicular to each other. • Orthogonal vectors are vectors that are perpendicular to each other.**

13.2 Resolution of vector

- **Resolving of a vector is the process of finding the components of a vector along x-, y-, and z- direction.**

- **Component of a vector is the projection of the vector on an axis.**

13.3 vector addition and subtraction

- **Vector addition is commutative and associative but vector subtraction is not commutative and associative.**

- **Vectors can be added by geographical method and component method.**

- **The unit vector of a given vector can be determined by dividing the vector by its magnitude.**

- **If two vectors are equal then they must have the same magnitude and the same direction.**

13.4 multiplications of vectors

- **Scalar (dot) product is the product of two vectors gives a scalar. It is expressed by** $A.B = |A||B|cos\theta = AxBx + AyBy + AzBz$

- **Properties of scalar product ; A.A=A2 , A.B =B.A , i.i= j.j = k.k=1, and i.j= j.k = k.i=0**
- **The projection of vector-A onto vector -B is given by** $A.cos\theta$
- **Vector (cross) product is the product of two vectors gives another vector.**
  $AxB = |A||B|sin\theta.\vec{n} = (AyBz - AzBy)i - (AxBz - AzBx)j + (AxBy - AyBx)k$
- **Properties of vector product are AxA=0 ,AxB= -BxA , ixi =jxj =kxk=0 , ixj=jxk=kxi=1**
- **The scalar product of two orthogonal vectors is always zero, and the vector product of two collinear vectors is always zero.**

Multiple choice I. Choose the best answer from the given alternative

1) **Which one of the following is a vector physical quantity?**

   A) Momentum B) energy C) time D) temperature

   Answer: A, momentum is a vector physical quantity

2) **Which one is not fundamental physical quantity?**

   A) Mass B) time C) speed D) temperature

   Answer: C, speed is derived physical quantity

3) **Let A= mi +2j +k, and B= i +j +3k, what is the value of 'm' such that A and B are orthogonal to each other?**

   A) -7 B) 7 C)4 D)3

   Answer: A, for orthogonal vectors, A.B= m+4+3=0, m= -7

4) **At what angle between vector -A and B such that** $|A.B| = |AxB|$**?**

   A) 300 B) 450 C) 600 D) 900

   Answer: B, $ABcos\theta$ **=** $ABsin\theta$ **,** $tan\theta = 1$ **,** $\theta = 45^0$

5) **Which one of the following is not correct? A) A.A =A2 B) AxA =0 C) AxB =BxA D) A.B =B.A**

   Answer: C, cross product is not commutative.

6) **. Let A+2B =i -2j +2k, and 3A-B = 2i +3j -k, what is vector -A?**

A) 5i +4j B) 1/7(5i +4j) C) 4i +5j D) 1/7(4i +5j)

Answer: B, since (A+2B) + (3A-B)= 1/7(5i +4j)

7) **What is a vector perpendicular to both vector-A = 2i+3j -k, and B= i -2j +2k?**

A) 4i +5j+ 7k B) 4i -5j -7k C) -4i -5j -7k D) 4i +4j -k

Answer: B, let C is a vector perpendicular to both vector -A and B then, C = A x B = 4i-5j -7k

8) **The sum and difference of two non- zero vector -A and B are equal in magnitude .what can you conclude about those two vectors?**

A) A and B have the same direction

B) A and B have opposite direction

C) A and B are perpendicular to each other

D) Vector -A greater than vector-B

Answer: C, since |A+B| =|A-B| ,$A2+B2+2ABcos\theta = A2+B2-2ABcos\theta; 4cos\theta = 0, \theta = 90^0$**.**

9) **If A = 8i +j -2k and B = 5i -3j +k ,then what is the value of AxB ?**

A)3i +4j -3k B) -3i -4j+ 3k C) -5i -18j -29k D) 5i +18j +29k

Answer: C, using determinant matrix

10) **What is the unit vector of A =2i +2j +k ?**

A) 1/3(2i +2j+k) B) i+ j+ k C) 1/3(i +j+k) D) i -j-k

Answer: A, since Unit vector of A is given by vector,-A divided by its magnitude

11) **Which of the following is a vector quantity? (UEE:2003)**

A. Power. C. Temperature B. Momentum. D. Electric current

Answer: B

12) **12. Which pair of forces CANNOT give a resultant of 5N? (UEE: 2003)**

A) 1N and 4N. B) 1N and 6N. C) 3N and 4N. D) 1N and 7N.

Answer: D

13) **The sum and difference of two non-zero vectors- A and B are equal in magnitude. What can you conclude about these two vectors? (UEE: 2004)**

A) A and B have the same direction.   C) A and B have the same magnitude.

B) A and B have opposite direction.

D.) A and B are perpendicular to each other.

Answer: D

14) **A vector that represents the position of an object in relation to another object is called (UEE: 2005)**

A. Unit vector.   B) Position vector.   C) Coplanar vector.   D) Collinear vectors

Answer:B

15) **Two non-vector- A and -B are related by A= c B, where c is a scalar. If the two vectors have opposite directions, then one of the following is true about c? (UEE: 2005)**

A. c is a positive number.   B. c is a negative number.   C) c=1   D. c=0

Answer:B

16) **Two non-zero vectors D and E have precisely equal magnitudes.Forth4 magnitude of D+E to be 3 times larger than the magnitude of D-E, what must be the angle between D and E?. A) 300.   B) 370.   C) 530   D) 600**

Answer: D

17) **What is the vector product of two vectors A=7i+4 j-2k , and B=3i-2j+5 k? (UEE: 2007).**

A) 16i-41 j-26k.   B) 4i-59j-26 k   C) -4 i+59j+26k   D) -36i-11j+ 2k

Answer:A

Chapter 14

THERMODYNAMICS

14.0 .1 Summary of the Unit

The key points of the unit are:

- **Zeroth law of thermodynamics states that if two objects A and B are separately in thermal equilibrium with a third object C, then A and B are in thermal equilibrium with each other**

- **Temperature is a property that determines whether an object is in thermal equilibrium with other objects.**

- **mass of substance (m), number of moles (n)and molar mass (M) are related as:**

$$n = \frac{N}{N_A} = \frac{m}{M} \tag{14.1}$$

- **and the mass of each particle is**

$$m_p = \frac{M}{N_A} = \frac{m}{N} \tag{14.2}$$

- **Absolute zero is the temperature at which all random motion of particles in a substance ceases.**

- **The first law of thermodynamics states that the change in internal energy of a**

closed system will be equal to the energy added to the system by heating minus the work done by the system on the surroundings.

$$\Delta U = Q - W \tag{14.3}$$

ΔQ	Positive	When heat is supplied to a system
	Negative	When heat is drawn from the system
ΔW	Positive	When work done by the gas (expansion)
	Negative	When work done on the gas (compression)
ΔU	Positive	When temperature increases, internal energy increases
	Negative	When temperature decreases, internal energy decreases

Fig. 14.1. conventions of first law

Directions of Thermodynamic Processes (Second law of thermodynamics)

- **Heat flows spontaneously from a hotter object to a cooler object, never the reverse.**
- **A reversible process, equilibrium process, is a process whose direction can be reversed by an infinitesimal change in the conditions of the process.**
- **Entropy is the measure of disorder in a system.**
- **The second law of thermodynamics can be stated in several equivalent ways:**
  a) **Heat flows spontaneously from a hot object to a cold one, but not the reverse.**
  b) **There can be no 100 percent efficient heat engine-that is, one that can change a given amount of heat completely into work.**

c) **Natural processes tend to move toward a state of greater disorder or greater entropy. The total entropy, S, of any system plus that of its environment increases as a result of any natural process it never decreases.**

Heat engines and maximum theoretical efficiency

- **A heat engine is a device that converts heat partly to mechanical work.**
- **The efficiency of a heat engine is given by**

$$\eta = 1 - \frac{Q_c}{Q_h} \tag{14.4}$$

- **The Carnot cycle (maximum efficiency) operates between two heat reservoirs at temperatures T_c and T_h uses only reversible processes. Its thermal efficiency is**

$$\eta_{max} = 1 - \frac{T_c}{T_h} \tag{14.5}$$

14.0 .2 Topic Related Questions and Brief Explanations on Thermodynamics

1) **100J of work is done on a system and 418.6 J of heat is extracted from it. According to the first law of thermodynamics, the change in the internal energy of the system is**

(A) 318.6J (B) 518.6 J (C) -518.6 J (C) -318.6 J Brief solution: From the first law of thermodynamics ΔU=Q-W. And using the right conventions of the first law of thermodynamics as W=-100J, Q=-418.6 J.

ΔU=Q-W

⇒ΔU=-418.6J-(-100J)⇔ ΔU=-318.6J

2) **In a reversible thermodynamic process, the system**

   A) is always close to equilibrium state.

   B) might never be close to any equilibrium state.

   C) is close to equilibrium state only at the beginning and end.

   D) is close to equilibrium states, throughout, except at the beginning and end.

   Brief explanation: reversible thermodynamic processes are in equilibrium within and with the external environment. All reversible processes are always close to equilibrium states. choice A is correct.

3) **A glass contains 12 mol of water molecule (H_2O). The number of water molecules, the mass of water, and the mass of each water molecule in the glass are, respectively (Molar mass of H is 1 g and O is 16 g)**

   A) 72.24x10^{23} molecules, 0.216kg, 29.9x10^{-26}kg

   B) 90.32x10^{23}molecules,0.192 kg,18x10^{-26}kg

   C) 102x10^{23} molecules,0.024 kg, 6.02x10^{-26} kg

   D) 96.32x10^{23} molecules,0.036 kg, 0.009x10^{-26} kg

   Brief solution

   $N_A = \frac{N}{n}$

   $\Rightarrow N = nN_A$

   $\Rightarrow$ **N=(12)(6.02)**$x10^{23}$

   $\Rightarrow N = 72.24x10^{23}$ **particles**

   $n = \frac{m_s}{M}$

   $\Rightarrow m_s = nM \Rightarrow m_s = (12)(18)$

   $\Rightarrow m_s = 216gm$

   $m_{each} = \frac{m}{N}$

   $\Rightarrow m_{each} = \frac{216}{72.24x10^{23}}$

$\Rightarrow m_{each} = 29.8x10^{-24}gm$

4) A sample mixture of gas contains 72 percent of hydrogen and 28 percent of Helium. What is the partial pressure of Helium at an atmospheric pressure of 76 cm of mercury (Hg)?

A) 54.72 cm of Hg B) 21.28 cm of Hg C) 33.44 cm of Hg **D) 76.0 cm of Hg**

Brief solution: The partial pressure of a gas depends on the amount of that gas in the container.

$Partialofgas$=$\frac{amountofthegas}{totalamountofgas}$

$\Rightarrow P_{He} = \frac{n_{He}}{n_{total}} P_{total} \Rightarrow P_{He} = \{\frac{28}{100}\} 76cmHg \Leftrightarrow P_{He} = 21.28cmHg$

5) An ideal gas is at a temperature of 300 K. If we wish to double the r-m-s speed of the molecules of the gas to what value must we raise the temperature?

A)450 K B) 600 K C) 800 K D) 1200 K

Brief solution : The r-m-s speed is given as $v_{rms} = \sqrt{\frac{3RT}{M}}$

$\Rightarrow v_{rms}^2 \sim T \Rightarrow \frac{v_{rms1}^2}{T_1} = \frac{v_{rms2}^2}{T_2}$

$\Rightarrow \frac{v_{rms1}^2}{T_1} = \frac{(2v_{rms1})^2}{T_2} \Rightarrow T_2 = 4T_1 \Rightarrow T_2 = 1200K$

6) Which one of the following statements is NOT correct?

A) The entropy of the universe increases in all-natural processes.

B) No heat engine operating in a cycle can absorb energy from a reservoir and use it entirely to do work.

C) When a system undergoes a change in state, the change in its internal energy is the difference between the energy transferred to it by heat and the work done on it.

D) The entropy of an isolated system reaches its maximum value when the system is in equilibrium state.

Brief explanation Choices A and B are undoubtedly true as both of them are statements of the second law of thermodynamics. Choice D is also TRUE. When the

system is in equilibrium state the processes are all REVERSIBLE, which means that Δ S= 0. The entropy cannot increase any more. It is at its maximum value. BUT choice C is NOT correct. When work is done on a system during its change from one state to another, the change in its internal energy is the sum between the energy transferred to it by heat and the work done on it.

7) **According to the kinetic theory of gases, the**

A) internal energy of an ideal gas is equal to the potential energy duet to interaction between the particles of the gas.

B) average translational kinetic energy of the particles of an ideal gas increases as the gas gets cooled.

C) particles of an ideal gas undergo inelastic collisions between themselves and with the walls of the container.

D) diffusion rate of gases is inversely proportional to the square root of the molar mass because it is directly proportional to the molecular speed.

Brief hints

The basics of molecular kinetic theory is to relate the microscopic gas properties with the macroscopic gas properties. According to this theory:

⇒ The internal energy of an ideal gas is a function of temperature only.

⇒ The internal energy of an ideal gas is the measure of average translational kinetic energy of molecules.

⇒ Particles of an ideal gas undergo elastic collisions

⇒ there is no interaction between gas molecules gravitationally.

⇒ Diffusion, mean free path, Brownian motion and speed distribution of molecules are best described using this theory.

⇒ the rate of diffusion is inversely proportional to the square root of molar mass of a gas since $v_{rms} = \sqrt{\frac{3RT}{M}}$

8) **A heat engine operating between 100^0C and 700^0C has efficiency equal to 40 percent of the maximum theoretical efficiency. How much energy does this engine extract from the hot reservoir in order to do 5000 J of mechanical work?**

A) 810.4 kJ **B) 81 kJ** **C) 20.2 kJ** **D) 14.4 kJ**

Brief solution

The efficiency and the maximum theoretical efficiency are mathematically given as

$\Rightarrow \eta = \frac{W}{Q_H}$ **and** $\eta_{max} = 1 - \frac{T_c}{T_H} \Leftrightarrow \frac{W}{Q_H}$**=** $\frac{40}{100}[1 - \frac{T_c}{T_H}]$

Note here that T_c **and** T_H **must be in Kelvin.**

$\Rightarrow \frac{5000}{Q_H}$**=1-**$\frac{373}{973} \Rightarrow Q_H = 20275.75J$

9) **Which of the following must be true about an ideal gas that undergoes an isothermal expansion?**

A) No heat enters the gas. **B) The pressure of the gas decreases.**

C) The internal energy of the gas does not change.

D) The gas does negative work.

Brief explanation: An isothermal process is a constant temperature process and the internal energy of an ideal gas is a function of temperature only.Therefore,the first law of thermodynamics takes the form for an isothermal process $\Rightarrow$ **Q=W. Choice C is correct**

10) **For a temperature increase of ΔT_1 , a certain amount of an ideal gas requires 30 J when heated at constant volume and 50 J when heated at constant pressure. How much work is done by the gas in the second situation?**

A) A) 20J **B) 30J** **C) 50J** **D) 80J**

Brief explanation:

$\Rightarrow$ **For any process on ideal gas the change in internal energy is $\Delta U = nc_v \Delta T$. More-**

over, ΔU is the same for the two processes (since the change in temperature is the same in both processes).

$\Rightarrow \Delta U_P=\Delta U_V \Rightarrow Q_P-W=Q_V \Rightarrow 50-W=30 \Rightarrow \underline{W=20\ J}$

• Remember that for the same change in temperature of an ideal gas the heat added at constant pressure is greater than the heat added at constant volume. ⋆($Q_P > Q_V$)

11) A refrigerator acts as:

A) a heat engine B) a heat pump

C) air cooler D) electric motor

• A refrigerator acts as a heat pump as it sends heat from sink (at lower temp.) to source (at higher temp.)

12) If the door of a refrigerator is kept open in closed room, then which of the following is true?

A) Room is cooled B) Room is heated

C) Room is cooled or heated depending upon its volume

D) Room is neither cooled nor heated

Brief Explanation

• In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber [$Q_1=Q_2+W$]. Therefore the room is heated.

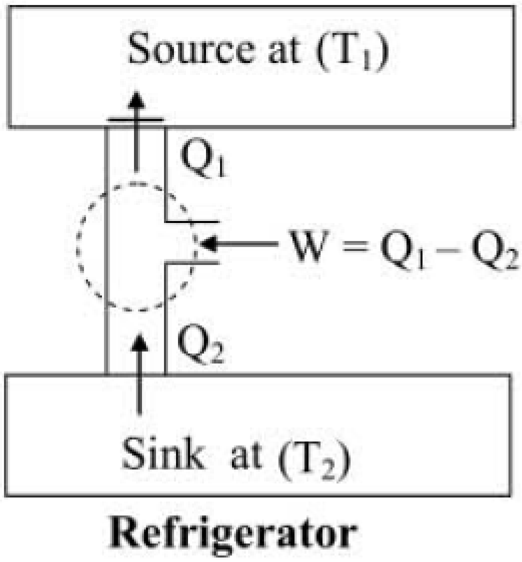


Fig. 14.2. refrigerators heat extraction

Chapter 15

OSCILLATIONS AND WAVES

15.0 .1 Summary of the Unit

15.0 .1.1 Simple Harmonic Motion

• Simple harmonic motion is an oscillatory motion where the acceleration is proportional to the displacement but opposite in sign.

• The defining equation of simple harmonic motion is

$$\overrightarrow{a}(t) = -\omega^2 \overrightarrow{x}(t) \tag{15.1}$$

The position ,velocity and acceleration of a SHO

$$x(t) = A\cos[\omega t \pm \phi] \tag{15.2}$$

$$v(t) = \frac{dx(t)}{dt} = -A\omega \sin[\omega t \pm \phi] \tag{15.3}$$

$$a(t) = \frac{dv}{dt} = -A\omega^2 \cos[\omega t \pm \phi] = -\omega^2 x(t) \tag{15.4}$$

• ϕ and A are uniquely determined from the initial position and velocity of the oscillator.

• depending on the direction of motion of the oscillator and its initial position, the position function of simple harmonic oscillator can be a function of sine or cosine.

•ϕ = $\pm\frac{\pi}{2}$ means that oscillator starts its mean (equilibrium)position.

•ϕ =0 means that the oscillator starts from extreme position.

• The velocity of a simple harmonic oscillator at any point is given by

$$v = \pm\omega\sqrt{A^2 - x^2} \tag{15.5}$$

• The total energy of a simple harmonic oscillator is proportional to the square of the amplitude.⇒ Total energy=$\frac{1}{2}$mω^2A^2

• When systems oscillate due to additional external force applied that has its own particular frequency,the oscillation is called forced oscillation.

• When the motion of the oscillator is reduced by an external dissipative force F$_d$, the amplitude decreases in time and the oscillation is called damped oscillation.

• Resonance occurs when an oscillator is driven at its natural frequency.At resonance

- **driven oscillator has same frequency as the frequency of the driving force**
- **energy is transferred easily to the oscillator**
- **the amplitude of the oscillator becomes maximum.**

Period and frequency of some oscillators

• Simple Pendulum

$$T = 2\pi\sqrt{\frac{L}{g}} \tag{15.6}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \tag{15.7}$$

• Mass spring system

$$T = 2\pi\sqrt{\frac{M}{k}} \tag{15.8}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \tag{15.9}$$

15.0 .1.2 Wave Motion

• A traveling wave or pulse that causes the elements of the disturbed medium to move perpendicular to the direction of propagation is called a transverse wave.
• A traveling wave or pulse that causes the elements of the medium to move parallel to the direction of propagation is called a longitudinal wave.
• The speed of a mechanical wave along a stretched string is given as $v = \sqrt{\frac{T}{\mu}}$
The phase speed of a wave is the rate at b b which the phase of the wave travels through space.$\Rightarrow$ **v**$_p$**=**$\frac{\lambda}{T}$
• Mathematical description of a traveling wave is

$$Y = A\sin[2\pi\frac{x}{\lambda} \pm 2\pi ft] \tag{15.10}$$

• The principle of super position states that if two or more traveling waves are moving through a medium, the resultant value of the wave function at any point is the algebraic sum of the values of the wave functions of the individual waves.
•The type of interference between two identical waves depend on the phase difference (or path difference) between the waves.
$\Rightarrow$ **constructive interference occurs when:** $\Delta r = [2n]\frac{\lambda}{2}$ **or** $\Rightarrow \phi = 2n\pi$**. n=0,1,2,3,...**
$\Rightarrow$ **destructive interference occurs when:** $\Delta r = (2n+1)\frac{\lambda}{2}$ **or** $\Rightarrow \phi = (2n+1)\pi$**. n=0,1,2,3,...**
• Standing waves are formed from the superposition of two sinusoidal waves having the same frequency, amplitude, and wavelength but traveling in opposite directions.
• The resultant standing wave is described by the wave function

$$Y = 2A\sin kx \cos \omega t \tag{15.11}$$

• The natural(harmonic) frequencies of vibration of a taut string of length L and fixed at both ends are quantized and are given by

$$f_n = n\frac{v}{2L} = \frac{n}{2L}\sqrt{\frac{T}{\mu}} \tag{15.12}$$

• The natural frequencies of vibration f_1, $2f_1$, $3f_1$, . . . form a harmonic series.

• Standing waves can be produced in a column of air inside a pipe. If the pipe is open at both ends, all harmonics are present and the natural frequencies of oscillation are

$$f_n = n\frac{v}{2L} \qquad n = 1,2,3,... \tag{15.13}$$

• If the pipe is open at one end and closed at the other, only the odd harmonics are present, and the natural frequencies of oscillation are

$$f_n = n\frac{v}{4L} \qquad n = 1,3,5,... \tag{15.14}$$

• The phenomenon of beating is the periodic variation in intensity at a given point due to the superposition of two waves having slightly different frequencies.

Sound Loudness and Intensity

• If a source of sound can be considered as a point, the intensity at a distance r from the source is inversely proportional to r^2. $\Rightarrow I_1 = \frac{P}{4\pi r_1^2}$

•The average intensity I_2 through a sphere with a different radius r_2 is given by a similar expression. If no energy is absorbed between the two spheres, the power P must be the same for both, and we have $\Rightarrow I_1 4\pi r_1^2 = I_2 4\pi r_2^2 \Leftrightarrow \frac{I_1}{I_2} = [\frac{r_2}{r_1}]^2$

• The intensity I at any distance r is therefore inversely proportional to r^2.

• The intensity level (or sound level) β of a sound wave is defined by the equation

$$\beta = [10 \log \frac{I}{I_0}] dB \qquad I_0 = 10^{-12} W/m^2 \tag{15.15}$$

•The Doppler effect is a change in the observed frequency of a wave when the source or the detector moves relative to the transmitting medium (such as air). For sound the observed frequency f' is given in terms of the source frequency f by

$$f' = f[\frac{v \pm v_D}{v \mp v_s}] \tag{15.16}$$

Topic Related Questions and Brief Explanations on Oscillation and Waves

1) What makes the oscillatory motion a simple harmonic motion?

A) The acceleration of the motion is directly proportional in magnitude but opposite in direction to the displacement.

B) The acceleration of the motion is directly proportional to the velocity.

C) The velocity of the motion is directly proportional to the displacement.

D) The velocity of the motion is inversely proportional to the displacement.

Brief explanation An object moves with simple harmonic motion whenever its acceleration is proportional to its position and is oppositely directed to the displacement from equilibrium. Choice A is correct.

2) which one of the following statements is correct about resonance in an oscillating object?

A) Resonance occurs when the oscillator is subject to a constant driving force.

B) Resonance occurs when the frequency of a periodic driving force is greater

than the natural of the oscillator.

C) Damping increases the amplitude and natural frequency of the oscillator.

D) At resonance, the driving frequency is equal to the natural frequency and the amplitude becomes maximum.

Answer. D

3) **A mass-spring system set to oscillate in a simple harmonic motion over frictionless horizontal surface. The amplitude of this oscillation is 20 cm. A second mass-spring system with the same spring constant is set to oscillate in the same way but with amplitude of 10 cm. The energy of the**

A) first mass-spring system has twice the second one.

B) second mass-spring system has half of the first one.

C) first mass-spring system has four times the second one.

D) second mass-spring system has the square of the first one.

Brief explanation: The total energy of a simple harmonic oscillator is proportional to the square of the amplitude. Choice A is correct

4) **Two successive transverse pulses, one caused by a brief displacement to the right and the other by a brief displacement to the left, are sent down a Slinky that is fastened at the far end. At the point where the first reflected pulse meets the second advancing pulse, the deflection**

(compared with that of a single pulse) is

A) quadrupled. B) doubled. C) canceled. D) halved.

Brief Explanation: The interference of two pulses that are completely out of phase results in a cancelation of resultant amplitude. Answer C

5) **A string vibrates with speed of 110 m/s in the fourth harmonic has a frequency of 880 Hz. What is the length of the string?**

A) 50.0 cm **B) 25.0 cm** **C) 31.3 cm** **D) 12.5 cm**

Brief explanation: for a standing wave along a stretched string the fourth harmonic is given by $f_4 = 4[\frac{v}{2L}] \Rightarrow 880 = 4[\frac{110}{2L}] \Rightarrow \underline{\underline{L = 0.25m}}$

6) **At t=0, an object undergoing SHM has maximum displacement of 0.650 m and angular frequency of 7.40 rad/s. which of the following is correct about the motion of the oscillator?**

A) The position of the object is $x = 0.65\sin(7.40t)$ **and its velocity is** $v = 4.81\cos(7.40t)$

B) The position of the object is $x = 0.65\cos(7.40t)$ **and its acceleration is** $a = -3.59\sin(7.40t)$ **C) The position of the object is** $x = 0.65\cos(7.40t)$ **and its acceleration is** $a = -35.9\cos(7.40t)$ **D) The frequency of the oscillator is 7.40 Hz and its period is 0.135 s**

Brief Explanations

The position function of a SHO is given as $x(t) = A\cos(wt + \phi)$**.**

Since the oscillator starts from extreme position, ϕ **=0 and hence the position function is**

$x(t) = A\cos(wt) \Rightarrow x(t) = A\cos(wt) \Rightarrow \underline{x(t) = 0.650\cos(7.40t)}$

$v = \frac{dx}{dt} = -(0.65)(7.4)\sin(7.4t) \Rightarrow \underline{v(t) = -4.81\sin(7.4t)}$

And the acceleration is $a = \frac{dv}{dt} = \frac{d^2x}{dt^2} \Rightarrow a = -(4.81)(7.4)\cos(7.4t) \Rightarrow \underline{a = -35.594\cos(7.4t)}$**.**

And the frequency$\Rightarrow f = \frac{\omega}{2\pi} = f = \frac{7.4}{2\pi} \Rightarrow \underline{f = 1.17Hz}$**.**

The Answer is choice C

7) **When a wave passes from one medium into another, which of these quantities must stay the same?**

A) wavelength **B) wave speed** **C) frequency** **D) direc-**

tion of propagation

Brief explanation: frequency changes only when the source changes. Answer Choice C

8) **A 0.35 kg mass attached to the end of a spring oscillates 2.5 times per second with amplitude of 0.15 m. Which of the following is true about the motion of the mass?**

A) The velocity when it passes the equilibrium is 2.355 m/s

B) The total energy of the system is 97.0J

C) The velocity when it is 0.10 m from equilibrium is 3.0 m/s

D) The acceleration when it is 0.10 m from equilibrium is 25.00 m/s^2.

Brief solution and explanation:

m=0.35 kg, and $f = \frac{numberofoscillations}{second} \Rightarrow f = 2.5Hz$**. A=0.15 m.**

A) when the oscillator passes through the equilibrium:

9) **x=0**

10) **the speed is maximum** $(v = \pm\omega A)$

11) **a=0 Therefore,** $v = 2\pi fA = 2.355m/s$

B) $E_T \sim A^2 \Rightarrow E = \frac{1}{2}mv_m^2$ $E = \frac{1}{2}m\omega^2A^2 \Rightarrow \frac{1}{2}(0.35)(2.35)^2 \Rightarrow$ $\underline{\underline{E_T\textbf{=0.97 J}}}$

C) at x=0.1 $v = \pm\omega\sqrt{A^2 - x^2}2\pi f\sqrt{0.15^2 - 0.1^2} \Rightarrow$ **v=1.75 m/s at x=0.1 m**

D) the acceleration at 0.1 from equilibrium is $a = -\omega^2A \Rightarrow \underline{\underline{a = 24.6m/s^2}}$**. choice A is correct.**

12) **Identify a true statement about a mechanical wave**

A) As a wave travels from one point to another along a medium, it transmits energy and particles of the medium from point to point.

B) The velocity of a traveling wave is equal to the velocity of the particles through which the wave propagates.

C) The speed of a wave traveling across a thin string is equal to its speed when traveling across a thick string of the same length and tension.

D) The speed of a wave traveling along a string increases as the tension in the string increases and as the linear density of the string decreases.

Brief hint

•As a wave travels from one point to another along a medium, it transmits energy but particles of the medium do not move along with the wave.

And the speed of a mechanical wave along a stretched string is $v = \sqrt{\frac{T}{\mu}}$ **where** $\mu = \frac{m}{L}$ **of the string.Choice D is True.**

13) **A wave traveling in the** $+ve$ **x-direction having displacement along y-direction as l m, wavelength** 2π **m and frequency of** $\frac{1}{\pi}$ **Hz is represented by**

A) $Y = \sin(x-2t)$ **B)** $Y = sin(2\pi x - 2\pi t)$ **C)** $Y = \sin(10\pi x - 20\pi t)$ **D)**$Y = \sin(2\pi x + 2\pi t)$

Brief hint

traveling wave is mathematically described as $Y = A\sin(kx \pm \omega)$. $-$ **sign is used for a wave traveling to the right.**$\Rightarrow Y = A\sin(\frac{2\pi}{\lambda} - 2\pi ft)$

Therefore, substituting the given values, $\underline{\underline{Y = \sin(x-2t)}}$**. Choice A is correct**

14) **The energy in the superposition of waves**

A) is lost. **B) increases.** **C) remains same only redistribution occurs** **D) may increase or decrease depending upon the medium.**

Hint: the energy remains conserved.

15) **Not only a change in direction but also a phase change of** π **radian is suffered by a sound wave. when it suffers**

A) refection from a denser medium. **B) reflection from a rarer medium.**

C) refraction in a denser medium. **D) refraction in a rarer medium.**

Brief explanation. on reflection from a denser medium, not only a phase change of

π but also the direction of propagation will change.

16) **If the velocity of sound in air is 350 m/s, then the fundamental frequency of an open organ pipe of length 50 cm will be**

A) 175 Hz **B) 350 Hz** **C) 900 Hz** **D) 750 Hz**

Solution

Fundamental frequency of open pipe is $f_1 = \frac{v}{2L} \Leftrightarrow \underline{\underline{f_1 = 350Hz}}$**. Answer B**

17) **In a closed pipe, the note of fundamental frequency can be produced if the length of the air column is equal to**

A) half the wavelength. **B) same as the wavelength.**

C) quarter the wavelength. **D) three quarters of the wavelength.**

Brief Explanation

Standing wave is created in a closed pipe if the length of the pipe is related with the wavelength as $\lambda = \frac{4L}{n}$ **where n=1,3,5,7...Choice C is correct.**

18) **The minimum length of a tube open at both ends that resonates with a tuning fork of frequency 350 Hz is**

(velocity of sound in air = 350 m/s) A) 0.25 m **B) 0.5 m** **C) 1 m** **D) 2 m**

Brief explanation.

Standing wave is created in an open pipe if the length of the pipe is related with wavelength of the sound as $\lambda = \frac{2L}{n}$**. The minimum length corresponds with the fundamental frequency** $\Rightarrow L = \frac{v}{2f_1} \Rightarrow \underline{\underline{L = 0.5m}}$**.**

19) **On sounding tuning fork A with another tuning fork B of frequency 384 Hz, 6 beats are produced per second. After loading the prongs of A with some wax and then sounding it again with B, 4 beats are produced per second. What is the frequency of the tuning fork A**

A) 328 Hz **B) 380 Hz** **C) 388 Hz** **D) 390 Hz**

Brief Explanation

up on loading tuning for A the beat frequency decreases from 6 to 4 beats per second. Therefore,$f_A > f_B \Rightarrow f_A - f_B = 6 \Rightarrow f_A = 390Hz$

20) **When a source of sound moves toward a stationary observer, the frequency of the sound heard by the listener is more than the actual frequency because the**

A)velocity of sound increases **B) apparent wavelength of sound decreases**

C) velocity and apparent wavelength of sound increases. **D) apparent wavelength of sound increases**

Brief explanation

When a source of sound moves relative to an observer, the cause of the shift in frequency is the decrease or increase of apparent wavelength. when a source moves toward a stationary observer, the apparent wavelength decreases and hence the frequency increases.

21) **The intensity of sound wave A is 100 times that of sound wave B. Relative to wave B the sound level of wave A is:**

A) -2dB **B) +2 dB** **C) +10 dB** **D) +20 db**

Brief solution

sound level of A relative to B is $\beta = 10\log\frac{I_A}{I_B}dB \Rightarrow \beta = 10\log\frac{100I_B}{I_B}dB \Rightarrow \underline{\beta = 20dB}$

22) **The sound level at a point P is 14 db below the sound level at a point 1.0m from a point source. The distance from the source to point P is:**

A) 4.0 cm **B) 202m** **C) 2.0m** **D) 5.0m**

Brief solution

Let the sound level at smaller distance be β_1 **and at larger distance be** β_2**. Then,**

$$\beta_1 - \beta_2 = 14 \Rightarrow 10\log(\frac{I_1}{I_2}) = 14 \Rightarrow 20\log(\frac{r_2}{r_1}) = 14 \Rightarrow r_2 = 10^{0.7}(r_1) \Rightarrow \underline{\underline{r_2 = 5m}}$$

Chapter 16

Wave Optics

16.1 Summary of the Unit

Key points of the unit:

- **A wavefront is a line joining all parts of a wave that are in phase.**
- **A wavefront is a surface of constant phase.**
- **Huygness Principle principle states that all points along a wave front produce a series of secondary wavelets. These wavelets travel at the same speed and have the same frequency as the original wave. The wavelets combine to form a new wavefront and this process continues. • Newton assumed that light is a stream of invisible particles, called corpuscles of negligible masses. Newton's theory took precedence over Huygens for the following reasons**
- **light was the only wave motion known to travel through vacuum**
- **light casts sharp shadow. If light was a wave diffraction would occur that avoids shadow.**
- **his fearsome reputation**

- **In order to observe interference in light waves, the following conditions must be met:**

- **The sources must be coherent**
- **they must maintain a constant phase with respect to each other.**
- **the waves must be same type.**
- **the waves must have the same frequency and hence speed and wavelength.**
- **To make the light sources Coherent and Monochromatic Young used:**
- **Filter: without the filter the fringes are blurred and consists of range of colors.**
- **single slit in front of the double slits ensures that the lights reach both slits in phase.**

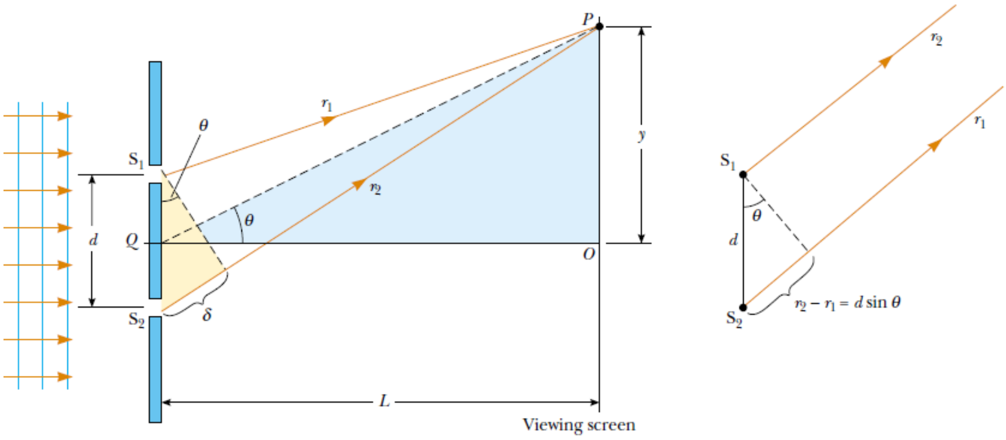


Fig. 16.1. oung's double slit experiment

• **constructive interference, at point P occurs when** $d\sin\theta = m\lambda$ **m=0,1,2,3,..**

• **destructive interference, at point P occurs when** $d\sin\theta = (m+\frac{1}{2})\lambda$

• **The vertical positions of the bright and dark fringes from the horizontal are given as**

$$Y_{bright} = m\frac{\lambda L}{d} \tag{16.1}$$

And

$$Y_{dark} = (m + \frac{1}{2})\frac{\lambda L}{d} \tag{16.2}$$

• **The interference pattern produced by a double slit comprises of a series of equal width maxima and minima known as fringes.**

• **The distance between successive bright and dark fringes is given by** $\Delta Y = \frac{\lambda L}{d}$

• **Thin film interference is due to the interference of light waves reflecting off the top surface of a film with those that have reflected off the bottom surface of the film.**

• **For constructive interference in thin films** $2nt = (m + \frac{1}{2})\lambda$ **and For destructive interference in thin films** $2nt = m\lambda$

•**The foregoing conditions for constructive and destructive interference are valid when the medium above the top surface of the film is the same as the medium below the bottom surface or, if there are different media above and below the film, the index of refraction of both is less than n. If the film is placed between two different media, one with** $n < n_{film}$ **and the other with** $n > n_{film}$**, then the conditions for constructive and destructive interference are reversed.**

• **Diffraction is the deviation of light from a straight-line path when the light passes through an aperture or around an obstacle.**

• **The amount of diffraction depends on the wavelength of the wave relative to the size of the gap.**

• **In a diffraction pattern minima occurs when** $a\sin\theta = m\lambda$ **where a is the slit width.**

• **The width of the central diffraction maxima is** $W_{central} = 2\frac{\lambda L}{a} = 2W_{othermax}$

• **A diffraction grating consists of a large number of equally spaced, identical slits.**

• **The condition for intensity maxima in the interference pattern of a diffraction grating for normal incidence is** $d\sin\theta = m\lambda$ **where** $d = \frac{W}{N}$**. N for number of slits and W width of the grating.**

Topic Related Questions and Brief Explanations on Wave Optics

1) **A young double slit experiment consists of two narrow slits separated by 0.06 mm and 1.2 m away from a screen. If the slits are illuminated with a light of wavelength 563 nm, the location of the fourth bright fringe on the screen is**

   A) 4.5 cm B) 0.45 cm C) 3.94 cm D) 0.394 cm

   Brief solution

   $Y_{bright} = m\frac{\lambda L}{d} \Rightarrow Y_4 = 4\frac{(563x10^{-9}m)(1.2m)}{6x10^{-5}} \Rightarrow \underline{Y_4 = 0.045m = 4.5cm}$

2) **A light wave of wavelength 590 nm pass through a narrow double slit of 0.2 mm slit separation. An interference is formed on a screen at a distance of 1.5 m. What is the distance between the consecutive bright fringes on the screen?**

   A) 0.43 mm B) 1.97 mm C) 44.3 mm 4.43 mm

   Solution

   The distance between successive fringes in young's double slit experiment is given by $\Delta y = \frac{\lambda L}{d} \Rightarrow \Delta y = \frac{(590\times10^{-9})(1.5m)}{2\times10^{-4}} \underline{\underline{\Delta y = 4.43mm}}$

3) **choose the correct statement about interference pattern due to diffraction of light through single and double slits.**

   A) The bright and dark fringes formed when light passes through double slits have equal width, whereas the central bright fringe fringe formed in single slit diffraction is twice as wider as the first order maxima.

   B) constructive interference due to double slit and single slit interference occur when the path difference between interfering waves is half-integer multiple of the wavelength.

C) The central bright fringe in both double and single slits interference are twice as wide as the first order bright fringes.

D) The light intensity of interference pattern due to double and single slit remain the same as distance from the central bright fringe increases.

Brief recap

• in single diffraction pattern, $W_{central} = 2W_{others}$

• constructive interference in YDSE occurs when $\Delta r = m\lambda$

• the intensity of interference pattern due the double and single slit pattern decreases as the distance from the center of the central peak increases.

4) In order for interference of light waves to occur, the interfering light waves should

A) be of different types B) have constant phase difference and the same frequency and speed C) be in phase D) be incoherent.

Brief explanation

in order to observe interference of light: The light sources should

- **be same type**
- **be able maintaining constant phase relationship. they don't have to be in phase,though.**
- **have the same frequency and speed.**

5) Which one of the following is correct about diffraction of light?

A) diffraction of light passing through a single slit produces bright and dark fringes of equal widths.

B) Diffraction of light passing through a circular aperture results in parallel bright and dark fringes.

C) As the number of slits of a grating increases, the bright fringes become brighter, taller and narrower.

D) As the width of a single slit decreases, the width of central bright fringe decreases too.

Brief Explanations

• **As the number of slits in a diffraction grating increases**

(a) **the number of subsidiary increases** $\Rightarrow$ **For N number of slits, there will be** $N-2$ **number of subsidiary**

(b) **the bright fringes become taller, brighter and narrower.**

• **The width of the central bright fringe in single slit is** $W=\frac{2\lambda L}{a}$

• **diffraction of light through a circular aperture results in a central bright spot called the Airy disc surrounded by concentric light and dark rings. The bright rings are much fainter than the Airy disc. Choice C is correct.**

6) **A wave front is a surface of constant:**

A) phase **B) frequency** **C) wavelength** **D) amplitude**

Answer A

7) **A screen is placed 50.0 cm from a single slit that is illuminated with light of wavelength 680 nm. If the distance between the first and third minima in the diffraction pattern is 3.00 mm, what is the width of the slit?**

A) 0.46 mm **B) 0.23 mm** **C) 0.54 mm** **D) 0.34 mm**

Brief solution

$L=50cm=\frac{1}{2}m, \lambda=680nm=680\times10^{-9}m, Y_3-Y_1=3\times10^{-3}$. **Then** $\Rightarrow Y_3-Y_1=\Delta Y=\frac{3\lambda L}{a}-\frac{\lambda L}{a}\Rightarrow\Delta Y=\frac{2\lambda L}{a}\Rightarrow a=\frac{2\lambda L}{\Delta Y}\Leftrightarrow \underline{a=0.23mm}$

8) What happens if the monochromatic light used in Young's double slit experiment is replaced by white light?

A) no fringes are observed **B) all bright fringes become white**

C) all bright fringes have colors between violet and red

D) only the central fringe is white, all other fringes are colored.

Brief explanation: If the light used in Young's double slit experiment is not monochromatic, the central fringe will be white and the rest contains a range of colors. Choice D is correct.

9) A wave traveling from a medium of index of refraction n_1**toward a medium of index of refraction** n_2 **undergoes partly transmission and partly reflection. If** n_2 **is greater than** n_1**. Which one of the following statements is correct?**

A) The speed of the wave in the medium with refractive index of n_1 **is smaller than** n_2

B) The incident and the reflected waves are in phase.

C) The angle of reflection is the same as the angle of incidence.

D) The refraction angle is less than the incidence angle.

Brief explanation: As waves travel from less dense to denser medium, their speed decreases and their phase shifts by $\frac{\lambda}{2}$**. And the angle of incidence and reflection are equal. However, the ray bends towards the normal and the angle of refraction will be less. Therefore, choice D is correct.**

10) Radio waves are diffracted by large objects such as buildings, whereas light is not noticeably diffracted. Why is this?

A) Radio waves are unpolarized, whereas light is plane polarized.

B) The wavelength of light is much smaller than the wavelength of radio waves.

C) The wavelength of light is much greater than the wavelength of radio waves.

D) Radio waves are coherent and light is usually not coherent.

Brief Explanation

The amount of diffraction of a wave depends on the size of the gap relative to the wavelength of the light. Longer wavelength waves easily diffracted than shorter. Answer B

11) At the second maxima on either side of the central bright spot in a double-slit experiment, light from

A) each opening travels the same distance.

B) one opening travels twice as far as light from the other opening.

C) one opening travels one wavelength of light farther than light from the other opening.

D) one opening travels two wavelengths of light farther than light from the other opening.

Brief explanation

In YDSE interference maxima occurs when $\Delta r = m\lambda$ and at the second maxima $m = 2 \Rightarrow \underline{\Delta r = 2\lambda}$. Answer D

12) The separation between adjacent maxima in a double-slit interference pattern using monochromatic light is

A) greatest for red light. B) greatest for green light. C) greatest for blue light. D) the same for all colors of light.

Brief explanation

Fringe spacing is given as $\Delta Y = \frac{\lambda L}{d}$ and down the spectrum of light, wavelength increases. Red is the largest wavelength in the spectrum. Answer A

13) The colors on an oil slick are caused by reflection and

A) diffraction. B) interference. C) refraction. D) polarization.

Brief explanation.

• **The colors seen on the surface of oil slicks and soap bubbles are due to the interference of light rays reflected from the top and bottom of thin films.Answer B**

14) Monochromatic light is normally incident on a diffraction grating that is 1 cm wide and has 10, 000 slits. The first order line is deviated at a 30^0 **angle. What is the wavelength, in nm, of the incident light?**

A) 300 B) 400 C) 500 D) 600

Solution

$W = 1cm, N = 10,000, \theta_1 = 30^0 \Rightarrow d\sin\theta_1 = \lambda, d = \frac{W}{N} = \frac{10^{-2}}{10^4} \Rightarrow d = 10^{-6}$**. Therefore,** $10^{-6}\sin 30^0 = \lambda \Rightarrow \underline{\lambda = 500nm}$**.**

15) At most, how many bright fringes can be formed on each side of the central bright fringe (not counting the central bright fringe) when light of 625 nm falls on a double slit whose spacing is 1.97×10^{-6} **?**

A) 1 B) 2 C) 3 D) 4

Solution

Interference maxima occurs when $d\sin\theta = m\lambda \Rightarrow \sin\theta = m\frac{\lambda}{d} \leq 1 \Rightarrow m \leq \frac{d}{\lambda} \Rightarrow m \leq \frac{1.97\times10^{-6}}{625\times10^{-9}} \Rightarrow m \leq 3.152$ **the highest order visible is thus the third order maximum**

Chapter 17

Electrostatics

17.1 Summary of the Unit

⋄ Electric field lines describe an electric field in any region of space. The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of E in that region.

⋄ Coulomb's law states that the electric force exerted by a charge q_1 on a second charge q_2 is $F_{12} = k\frac{q_1 q_2}{r^2}$

⋄ At a distance r from a point charge q, the electric field due to the charge is given by $k\frac{q}{r^2}$.

⋄ Gauss' law states that the electric flux through any closed surface is proportional to the enclosed electric charge.

⋄ Electric flux is proportional to the number of electric field lines that penetrate a surface. If the electric field is uniform and makes an angle θ with the normal to a surface of area A, the electric flux through the surface is $\phi = EA\cos\theta$.

⋄ A conductor in electrostatic equilibrium has the following properties:

a) The electric field is zero everywhere inside the conductor

b) Any net charge on the conductor resides entirely on its surface.

c) The electric field just outside the conductor is perpendicular to its surface and has a magnitude $\frac{\sigma}{\varepsilon_0}$, where σ is the surface charge density at that point.

d) On an irregularly shaped conductor, the surface charge density is greatest where the radius of curvature of the surface is the smallest. ◇ The work W done by the electric-field force on a charged particle moving in a field can be represented in terms of potential energy U: $W_{a \to B = U_a - U_b}$

The potential energy for a point charge q' moving in the field produced by a point charge q at a distance r from q' is $U = k\frac{qq'}{r}$

◇ Electric Potential, a scalar quantity denoted by V, is potential energy per unit charge. The potential at any point due to a point charge is $V = \frac{U}{q} = k\frac{q}{r}$

◇ An equipotential surface is a surface on which the potential has the same value at every point. At a point where a field line crosses an equipotential surface, the two are perpendicular. When all charges are at rest, the surface of a conductor is always an equipotential surface, and all points in the interior of a conductor are at the same potential.

◇ The Millikan oil-drop experiment determined the electric charge of individual electrons by measuring the motion of electrically charged oil drops in an electric field. The size of a drop is determined by measuring its terminal speed of fall under gravity and the drag force of air.

◇ When a dipole is placed within an electric field the moment leads to a turning effect,orienting the dipole with the electric field.

◇ A capacitor consists of any pair of conductors separated by vacuum or an insulating material. A parallel-plate capacitor is made with two parallel plates, each with area A, separated by a distance d. If they are separated by vacuum, the capacitance is $C = \varepsilon_0 \frac{A}{d}$

◇ When capacitors with capacitances $C_1, C_2, C_3, ...$ are connected in series, the equivalent capacitance is given by $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$

◇ When they are connected in parallel, the equivalent capacitance is $C_{eq} = C_1 +$

$C_2 + C_3 + ...$

◇ **The energy U required to charge a capacitor C to a potential difference V and a charge Q is equal to the energy stored in the capacitor and is given by** $U = W_{total} = (\frac{V}{2})Q = \frac{Q^2}{2C} = \frac{1}{2}CV^2$

◇ **The energy can be thought of as residing in the electric field between the conductors; the energy density u (energy per unit volume) is** $\frac{1}{2}\varepsilon_0 E^2$

◇ **When the space between the conductors is filled with a dielectric material, the capacitance increases by a factor K called the dielectric constant of the material** $C = k\varepsilon_0 \frac{A}{d}$**.**

◇ **When the charges**$\pm Q$ **on the plates remain constant, charges induced on the surface of the dielectric decrease the electric field and potential difference between conductors by the same factor K. :**

- **Filter circuits**
- **smoothing circuits**
- **tuning circuits**

Other uses of capacitors are:

- **capacitor microphone**
- **displacement sensors**
- **preventing sparking and as a counter in digital electronics.**

17.2 Topic Related Questions and Brief Explanations on Electrostatics

1) **One of the following statements is a correct description of the charging processes?**

A) when a plastic rod is rubbed with wool, the two objects acquire a net charge of

the same sign.

B) When a positively charged object is momentarily brought in to contact with a neutral metallic sphere, the spheres acquire a net positive charge.

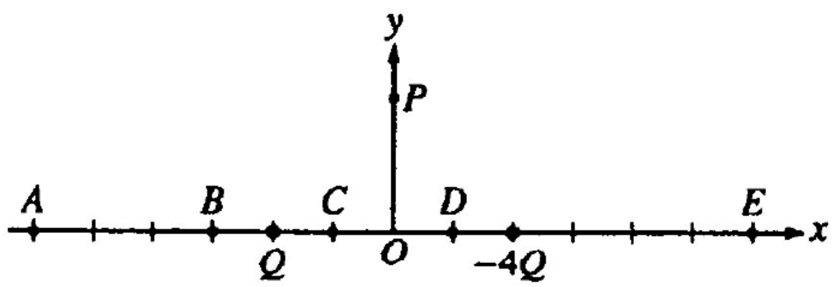
C) When a neutral metallic sphere is charged by induction using a negatively charged rod, the sphere acquire a net negative charge.

D) During charging a neutral object by induction using a negatively charged rod, charge flows from the rod to the object.

Brief Explanation

- **In charging by rubbing we always end up with two objects of opposite charge.**
- **Charging by Conduction: A charged object, when brought into physical contact with a second object, may share some or all of its charges with the second object. Thus the second object gets the same type of charge as the first object originally had.**
- **When a neutral metallic sphere is charged by induction using a negatively charged rod, the sphere acquire a net positive charge.**

Answer is B



2) **Particles of charge Q and $-4Q$ are located on the x-axis as shown in the figure above. Assume the particles are isolated from all other charges. Which of the following describes the direction of the electric field at point P?**

A) $+x$ **B)** $+y$ **C)** $-y$ **D) Components in both the** $-x$ **and** $+y$ **directions** **E) Components in both the** $+x$ **and** $-y$ **directions**

Brief Solution

Electric field lines begin on positive charge and end on negative charge. The electric field from charge $+Q$ will point upward and to the right at P. The electric field from charge $-4Q$ will point downward and to the right at P. Both charges are the same distance from P and both produce a field which points to the right. Since the magnitude of the $-4Q$ charge is greater, its field in the y dimension cancels the field from the $+Q$ charge and the y-component of the field at point P is downward.

Answer E

3) **A parallel plate capacitor is charged with a battery. The battery is then disconnected,and a dielectric material is inserted between the plates of the capacitor. Which of the following is correct about the effect of the dielectric?**

A) The capacitance remains the same and the electric field between the plates increases.

B) The electric field between the plates and the energy stored decrease.

C) The charge on the plates decreases and the energy stored increases.

D) The potential difference between the plates remains the same and the charge increases.

Brief Explanation

When the charges $\pm Q$ on the plates remain constant,that happens when the capacitor is isolated, charges induced on the surface of the dielectric decrease the electric field and the energy.

Answer B.

4) **Sphere A carries a net positive charge, and sphere B is neutral. They are placed near each other on an insulated table. Sphere B is briefly touched with a wire that is grounded. Which statement is correct?**

A) Sphere B remains neutral.

B) Sphere B is now positively charged.

C) Sphere B is now negatively charged.

D) The charge on sphere B cannot be determined without additional information.

Answer C

5) Many chemical reactions release energy. Suppose that at the beginning of a reaction, an electron and proton are separated by $0.110nm$, and their final separation is $0.100nm$. How much electric potential energy was lost in this reaction (in units of eV)?

A) 27.5 eV **B) 14.4 eV** **C) 13.1 eV** **D) 1.30 eV**

Brief Solution

Solution

The potential energy of the two-charge configuration (assuming they are both point charges) is given $U_e = PE = -k\frac{e^2}{r} \Rightarrow \Delta U_e = U_F - U_I = ke^2(\frac{1}{r_0} - \frac{1}{r_F})$

$\Rightarrow \Delta U_e = (9\times10^9)(1.6\times10^{-19})^2(\frac{1}{0.11x10^{-9}} - \frac{1}{0.1\times10^{-9}})$.

$\Rightarrow \Delta U_e = 2.07\times10^{-19}J$

And since, $1eV = 1.6\times10^{-19} \Rightarrow \Delta U_e = 1.30eV$. **Answer D**

6) Four identical point charges are arranged at the corners of a square [Hint: Draw a figure]. The electric field E and potential V at the center of the square are

A) $E=0, V=0$ **B)** $E=0, V\neq0$ **C)** $E\neq0, V\neq0$ **D)** $E\neq0, V=0$

Brief Explanation

The net electric field at the center is the vector sum of the electric fields due to each charge. The fields will have equal magnitudes at the center, but the fields from the charges at opposite corners point in opposite directions, so the net field will be zero. The electric potential from each charge is a nonzero scalar. At the

center the magnitudes of the four potentials are equal and sum to a nonzero value.

Answer B

7) **A battery establishes a voltage V on a parallel-plate capacitor. After the battery is disconnected, the distance between the plates is doubled without loss of charge. Accordingly, the capacitance —— and the voltage between the plates ——-.**

A) increases; decreases. **B) decreases; increases.**

C) increases; increases. **D) decreases; decreases.**

Brief Explanation

When the plates were connected to the battery, a charge was established on the plates. As the battery is disconnected, this charge remains constant on the plates. The capacitance decreases as the plates are pulled apart, since the capacitance is inversely proportional to the separation distance. For the charge to remain constant with smaller capacitance, the voltage between the plates increases.

$Q_1 = Q_2 \Rightarrow C_1V_1 = C_2V_2 \Rightarrow \frac{\varepsilon_0 A}{d_1} = \frac{\varepsilon_0 A}{2d_1} \Rightarrow V_2 = 2V_1$

8) **Consider a parallel plate capacitor with plate area A, plate separation d, Charge Q, Capacitance C, Potential difference V and electric field E between the plates. The electrical energy density stored by the capacitor**

A) depends on the plate area A and plate separation d.

B) increases as the capacitance C and potential difference V increase.

C) is directly proportional to the electric field E between the plates.

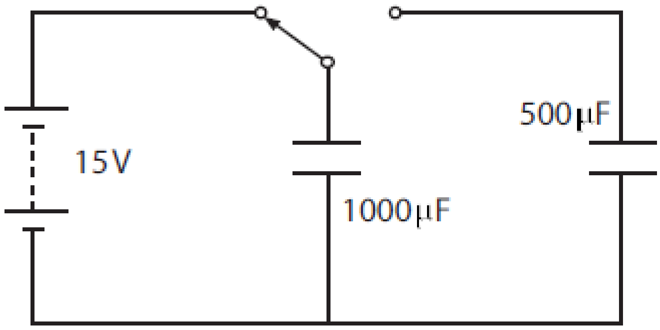
D) is directly proportional to the square of the electric field E between the plates.

Brief Hint: The electrical energy density of a parallel plate capacitor is given as $u = \frac{U}{V} = \frac{1}{2}\varepsilon_0 E^2$**. Answer D.**

9) **A** 1000μ **F capacitor is charged from a 15 V dc supply through a two way switch. The switch is thrown to connect it to uncharged** 500μ **F capacitor as shown. What**

is the initial and the final charge on the $1000\mu F$ capacitor?

A) $10,000\mu C and 15000\mu C$ **B)** $15000\mu C and 10,000\mu C$



C) $5,000\mu C and 10,000\mu C$ **D)** $10,000\mu C and 5,000\mu C$

Brief solution

Initially the source was connected with $1000\mu F$ capacitor and hence the initial charge it stores is $Q_0 = CV_0 = (1000\mu F)(15) \Rightarrow \underline{Q_0 = 15000\mu C}$.

After the switch is thrown to connect it to the uncharged $500\mu F$ capacitor, $Q_1 + Q_2 = 15,000\mu C$ and the charge is shared till each plate has the same potential. After equilibrium is reached, $\frac{Q_1}{C_1} = \frac{Q_2}{C_2}$. Where Q_1 is the charge on the 1000μ F capacitor after connected with the 5000μ F capacitor.

$\Rightarrow Q_2 = (\frac{C_2}{C_1})Q_1) \Rightarrow Q_2 = (\frac{1}{2})Q_1 \Rightarrow Q_1 + \frac{Q_1}{2} = 15000\mu C \Rightarrow \underline{Q_1 = 10,000\mu C}$ **and** $Q_2 = 5,000\mu C$**.**

Answer is B.

10) $Q_1 = -0.1\mu C$ **is located at the origin.** $Q_2 = +0.1\mu C$ **is located on the positive x axis at** $x = 0.1m$ **Which of the following is true of the force on** Q_1 **due to** Q_2**?**

A) It is attractive and directed in the $+x$ direction.

B) It is attractive and directed in the $-x$ direction.

C) It is repulsive and directed in the $+x$ direction.

D) It is repulsive and directed in the $-x$ direction.

Brief explanation

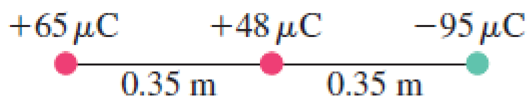
The two charges have opposite signs, so the force is attractive. Since Q_2 is located

on the positive x axis relative to Q_1 at the origin, the force on Q_1 will be in the positive x direction.

11) **Particles of charge and are placed in a line $+65\mu C$, $+48\mu C$ and $-95\mu C$. The center one is 0.35 m from each of the others. What is the net force on the $+65\mu C$?**

A) $-120N$to the left **B) $+560N$ to the right**

C) $-45N$ to the left **D) $+120N$ to the right.**



Brief solution

Let the right be the positive direction on the line of charges. Use the fact that like charges repel and unlike charges attract to determine the direction of the forces.

$F_{65} = -k\frac{(65\mu C)(48\mu C)}{(0.35)^2} + k\frac{(65\mu C)(95\mu C)}{(0.7m)^2} \Rightarrow F_{65} = -115.65N \simeq -120N$ **to the left.**

12) **In a certain region of space, the electric potential increases uniformly from east to west and does not vary in any other direction. The electric field:**

A) points east and varies with position

B) points east and does not vary with position

C) points west and varies with position

D) points west and does not vary with position

Brief Hint:

The electric field is directed along the direction of decreasing potential. Therefore, the electric field must be directed along the east direction. Choice A is correct.

13) **The torque exerted by an electric field on a dipole is:**

A) parallel to the field and perpendicular to the dipole moment

B) parallel to both the field and dipole moment

C) perpendicular to both the field and dipole moment

D) parallel to the dipole moment and perpendicular to the field

Brief explanation

The torque acting on an electric dipole in uniform electric field is given by $\overrightarrow{\tau} = \overrightarrow{P} \times \overrightarrow{E}$. Therefore, the torque is perpendicular to both P and E. Choice C is correct.

14) An air-filled parallel-plate capacitor has a capacitance of $1.3pF$. The separation of the plates is doubled, and wax is inserted between them. The new capacitance is $2.6pF$. Find the dielectric constant of the wax.

A) 2 **B) 4** **C) 6** **D) 8**

Solution

$C_0 = 1.3pF = \frac{\varepsilon_0 A}{d}$ **and** $C = 2.6pF = \frac{k\varepsilon_0}{2d} \Rightarrow 2.6 = k\frac{1.3}{2} \Rightarrow k = 4$.

15) Three capacitors of capacitances, $8\mu F, 12\mu F, and 24\mu F$ are connected (a) in series and then (b) in parallel. What is the ratio of the equivalent capacitance in case (a) to that in case (b)?

A) 1:11 **B) 11:1** **C) 1:1** **D) 1:3**

Solution

$\frac{1}{C_{series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow \frac{1}{C_{series}} = \frac{1}{8\mu F} + \frac{1}{12\mu F} + \frac{1}{24\mu F} \Rightarrow C_{series} = 4\mu F$ **and** $C_{parallel} = C_1 + C_2 + C_3 \Rightarrow C_{parallel} = 44\mu F$. **Therefore,** $\frac{C_{series}}{C_{parallel}} = 1 : 11$

Chapter 18

Steady Electric Current and Circuit Properties

18.1 Summary of the units

Basic principles

• **The current in a conductor is related to the motion of the charge carriers through the relationship** $I = nqv_dA$**.**

• **The current density in an ohmic conductor is proportional to the electric field according to the expression** $\overrightarrow{J} = \sigma\overrightarrow{E} = \frac{E}{\rho}$**.**

• **For a uniform block of material of cross sectional area A and length** ℓ **the resistance over the length** ℓ **is** $R = \rho\frac{\ell}{A}$**.**

• **The** *emf* **of a battery is the maximum possible voltage that the battery can provide between its terminals.**

• **the terminal voltage of the battery is given as** $V_{ab} = \varepsilon - Ir$**. The** $emf = \varepsilon$**, is equivalent to the open-circuit voltage that is,the terminal voltage when the current is zero.**

• **power delivered by the battery and power delivered to R and r are related as** εI=$I^2R +$

I^2r.

• **the equivalent resistance of a series connection of resistors is the numerical sum of the individual resistances and is always greater than any individual resistance** $\Rightarrow R_e = R_1 + R_2 + R_3 + - - -$. **The equivalent resistance of resistors in parallel is given as** $\frac{1}{Re} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + - - -$. **Furthermore, the equivalent resistance is always less than the smallest resistance in the group.**

• **Kirchhoffs rules:**

a) **Junction rule. The sum of the currents entering any junction in a circuit must equal the sum of the currents leaving that junction:** $\sum I_{IN} = \sum I_{out}$. **This rule is a statement of conservation of electric charge.**

b) **Loop rule. The sum of the potential differences across all elements around any closed circuit loop must be zero:** $\sum V = 0$. **The loop rule follows from the law of conservation of energy.**

Measuring Instruments

- **The Ammeter**
  - **A device that measures current is called an ammeter.**
  - **Ammeter must be connected in series with other elements in the circuit**
  - **Ideally, an ammeter should have zero resistance so that the current being measured is not altered.**

- **The Voltmeter**
  - **A device that measures potential difference.**

• An ideal voltmeter has infinite resistance so that no current exists in it.

- **The Galvanometer**

• The basic operation of the galvanometer uses the fact that a torque acts on a current loop in the presence of a magnetic field.

• To convert a galvanometer into ammeter, a shunt (a very small resistance) in parallel is connected. If I_g is full scale deflection through the galvanometer and R_g is its internal resistance then to convert it into an ammeter that measures I, a shunt R_s will be required in parallel such that $R_s = (\frac{I_g}{I-I_g})R_g$.

• To convert a galvanometer in to a voltmeter to measure V volts a resistor R is to be connected in series given by $R = \frac{V}{I_g} - R_g$.

- **Wheatstone bridge**

• Wheatstone bridge is the accurate arrangement of four resistances used to measure one (unknown) of them in terms of the rest of them.

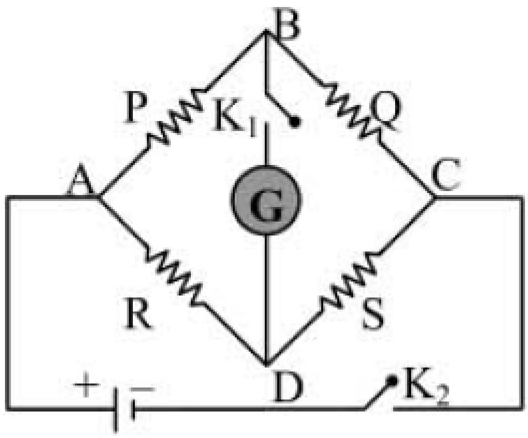


Fig. 18.1. wheatstone bridge circuit

The condition for a balanced bridge is $\frac{P}{Q} = \frac{R}{S}$

18.1 .1 Related Questions and Solutions On the unit

a) **which of the following statement is correct about the resistance of a conductor with a circular cross section?**

A) The resistance of the conductor decreases as it is heated.

B) The resistance of the conductor increases as its length and diameter increases.

C) The resistance of the conductor increases as its length increases and its diameter decreases.

D) At a given temperature,the resistance of copper and silver wires of the same length and diameter is the same.

Hint: $R = \rho\frac{\ell}{A}$**. Answer is C**

b) **Kichhoff's junction rule states that**

A) charge entering the junction equals the charge leaving that junction at a particular time.

B) the sum of the voltage drop across any closed loop equals the sum of electromotive force.

C) current traversing any closed loop at a particular time is zero.

D) The potential drop at a given junction equals the electromotive force at that particular point.

Answer A

c) **A potential difference V is applied across the ends of a uniform conducting wire of length L, cross sectional area A, and containing n free charge carriers per unit volume. Which one of the following is true?**

A) The free electrons in the conductor flow in the opposite direction of the electric field in the conductor.

B) The electric current in the conductor flows arbitrarily in all directions.

C) The electric current in the conductor flows perpendicularly to the drift velocity

of the free charges.

D) The current density in the conductor is directed in the direction of the drift velocity.

Hint: Despite the collisions, the electrons move slowly along the conductor (in a direction opposite that of E) at the drift velocity v_d. Answer A.

d) A cylindrical copper rod has resistance R. It is reformed to twice its original length with no change of volume. Its new resistance is

A) R B) 2R C) 4R D) $\frac{R}{2}$.

Brief solution

Initial geometrical values: $L_0 = L, A_0 = A, R_0 = \frac{\rho L_0}{A_0}$.

Final geometrical values $L_F = 2L_0, V = V_0 \Rightarrow A_0 V_0 = AL \Rightarrow A_0 L_0 = A2(L_0) \Rightarrow A = \frac{A_0}{2}$.

Therefore, the final resistance is $R = \frac{\rho L}{A} \Rightarrow R = \frac{\rho(2L_0)}{\frac{A_0}{2}} \Rightarrow \underline{R = 4R_0}$.

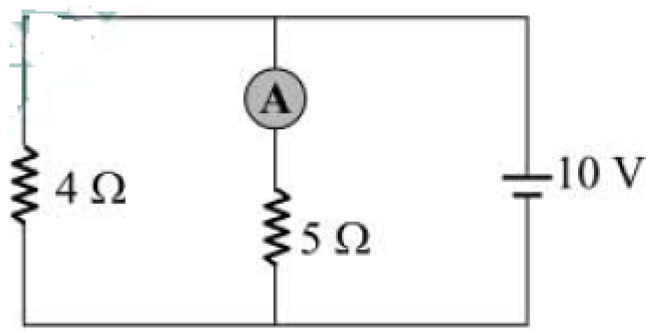
e) If the current carried by a conductor is doubled, what happens to the electron drift velocity?

A) doubles B) halved C) remains unchanged D) quadrupled

Brief explanation.

From the microscopic definition of an electric current $I = nqv_dA \Rightarrow I \sim v_d$. **So the answer is A.**

f) In the circuit given, the reading of the ammeter is

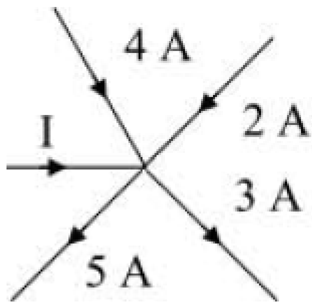


A) $\frac{40}{29}A$ **B)** $\frac{10}{9}A$ **C)** $\frac{5}{3}A$ **D) 2 A**

Short solution

Since the 4Ω **and the** 5Ω **are connected in parallel, they share same V across each as the source.**$V_{5\Omega} = V_{4\Omega} = 10V$. **Therefore,**$I_{5\Omega} = I_{ammeter} = \frac{V}{5\Omega} \Rightarrow \underline{\underline{I_{ammeter} = 2A}}$

g) **In the given current distribution, what is the value of I?**



A) 3A **B) 8 A** **C) 2 A** **D) 5 A**

Brief explanation

From Kirchhoff's junction rule, the $\Sigma I_{IN} = \Sigma I_{out} \Rightarrow 4+2+I = 3+5 \Rightarrow \underline{\underline{I = 2A}}$

h) **A certain galvanometer has a resistance of** 100Ω **and requires 1mA for full scale deflection. To make this into a voltmeter reading 1V full scale, connect a resistance of:**

A) 1000 Ω in parallel **B) 900 Ω in series** **C) 1000 Ω in series** **D) 10 Ω in parallel**

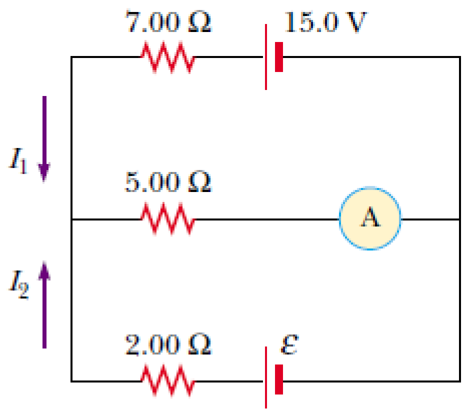
Brief explanation and solution

To use a galvanometer as a voltmeter that can read large voltages,we connect large resistance in series with the galvanometer given by $R = \frac{V}{I_g} - R_g \Rightarrow R = \frac{1V}{10^{-3}A} - 100\Omega \Rightarrow \underline{\underline{R = 900\Omega}}$.

i) **The ammeter shown in the figure reads 2A. What is the values of** I_1, I_2 **and** ε.

Brief explanation and solution applying the loop rule to the top loop: $+15.0 - (7)I_1 - (2)(5) = 0 \Rightarrow I_1 = \frac{5}{7}A$. **And applying the junction rule :**$I_3 = I_1 + I_2 = 2A \Rightarrow I_2 = \frac{9}{7}A$.

Again applying the loop rule to the bottom loop: $+\varepsilon - (2)\frac{9}{7} - 5(2) = 0 \Rightarrow \varepsilon = 12.6V$



j) **A long straight wire carries a current of 35 A. What is the magnitude of the field B at a point 20 cm from the wire?**

A) 3.5 $\times 10^{-5}$ **T** **B) 3.5** $\times 10^{-2}$ **T** **C) 7** $\times 10^{-5}$ **T** **D) 3.5** $\times 10^{-3}$ **T**

Solution

I = 35 A, r = 20 cm = 0.2 m. Magnetic field due to long straight wire is $B = \frac{\mu_0 I}{2\pi r} \Rightarrow B = 3.5 \times 10^{-5} T$

k) **The direction of the force on a current carrying wire in a magnetic field is described by which of the following?**

A) perpendicular to the current only

B) perpendicular to the magnetic field only

C) perpendicular to both the current and the magnetic field

D) perpendicular to neither the current or the magnetic field

Brief solution

The force acting on a current carrying condcutor is $F_B = I\overrightarrow{L} \times \overrightarrow{B}$**. The force is perpendicular to both the current and the magnetic field.**

l) **A vertical wire carries a current straight up in a region where the magnetic field vector points due north. What is the direction of the resulting force on this current?**

A) down **B) north** **C) east** **D) west**

Hint: Use Right hand rule. choice D is correct.

m) What is the expression of the centripetal acceleration of a particle of charge q and mass m moving in a magnetic field B on a circle of radius r if $\overrightarrow{B}$ is perpendicular to the particles's direction of motion?

A) $\frac{qB}{m}$ **B)** $\frac{2qB}{mr}$ **C)** $\frac{q^2B^2}{m}r$ **D)** $\frac{q^2B^2}{m^2}r$

Brief solution

$a_c = \frac{mv^2}{r}$ **and** $v = \frac{qrB}{m}$**. Therefore, substituting for v in the centripetal acceleration** $a_c = \frac{q^2B^2}{m^2}r$

n) Two long wires of 10 m in length carries a current of 2.0 A and 0.5 A in the same direction. The wires are separated by 4.0 cm. What is the magnetic force that the wires exert on each other?

A) 5×10^{-5} **N** **B)** 5×10^{-7} **N** $C)5 \times 10^{-6}$ **N** **D)** 4×10^{-6} **N**

Brief solution and recap

Parallel wires carrying current in the same direction attract each other.

The force exerted on each other is $F = \mu_0 \frac{I_1 I_2}{2\pi d} L = \frac{4\pi \times 10^{-7} \times 2 \times 0.5}{4 \times 10^{-2} \times 2\pi} 10 \Rightarrow F_B = 5 \times 10^{-5} N$**.**

o) A tangent galvanometer has 28 turns and diameter of 22 cm. when a current of 0.2 A is passed it gives a deflection of 45^0. What is the horizontal component of earths magnetic field?

A) $1.6x10^{-5}$ **T** **B)** $2.6x10^{-5}$ **T** **C)** $3.2X10^{-6}T$ **D)** $3.2x10^{-3}T$

Solution

$B_H = \frac{B_C}{tan\theta} \Rightarrow B_H = B_C = \mu_0 \frac{NI}{2R} = 3.2x10^{-3}$**.**

p) The vertical component of earths magnetic field is zero at

A) magnetic equator **B) magnetic poles** **C) geographic**

poles D) everywhere.

Hint:

Near the equator the angle of dip is close to zero and the vertical component of Earth's magnetic field is zero around the equator.

q) **A wire carries a current directly away from you.Which way do the magnetic field lines produced by this wire point?**

A) They point parallel to the wire in the direction of the current.

B) They point toward the wire.

C) They point away from the wire.

D) They make circles around the wire.

Brief explanation

The direction of electric fields may which point toward or away from the charge. However, the magnetic field lines always make circles around the current. Answer is choice D.

r) **A thin** $12cm$**long solenoid has a total of 460 turns of wire and carries a current of 2.0 A. Calculate the field inside the solenoid near the center.**

A) $9.6\times10^{-3}T$ **B)** $9.4\times10^{-3}T$ **C)** $9.6\times10^{-2}T$ **D)** $9.4\times10^{-2}T$

Solution

$B=\mu_0\frac{N}{\ell}I\Rightarrow B=\frac{4\pi\times10^{-7}(460)(2)}{0.12}\Rightarrow \underline{\underline{B=9.6\times10^{-3}T}}$

s) **which one of the following statements is NOT correct about the magnetic properties of matter?**

A) The unpaired electrons in the ferromagnetic materials will align with the applied magnetic field and parallel to each other.

B) The unpaired electrons in paramagnetic substance which will tend to align themselves in the same direction as the applied magnetic field.

C) There is a tendency to oppose the applied magnetic field in a diamagnetic substance.

D) The unpaired electrons in diamagnetic materials will align with the applied magnetic field and parallel to each other.

Brief recap

There are NO UNPAIRED electrons in diamagnetic materials. Choice D is not correct.

t) velocity selector consists of electric and magnetic fields described by the expressions $\overrightarrow{E} = E\hat{k}$ and $\overrightarrow{B} = B\hat{j}$, with $B = 15.0mT$. Find the value of E such that a $750eV$ electron moving along the positive x axis is undeflected.

A) 122 kV/m B) 144 kV/m C) 244 kV/m D) 222 kV/m

Brief Explanation and solution

In a velocity selector charges move undeflected with a speed $v = \frac{E}{B} \Rightarrow E = vB$ and $1eV = 1.6 \times 10^{-19}J$. Another relationship is that $v = \sqrt{\frac{2KE}{m}} \Rightarrow E = \sqrt{\frac{2KE}{m}}B \Rightarrow E = \sqrt{\frac{2\times750\times1.6\times10^{-19}}{9.11\times10^{-31}}}(15 \times 10^{-3}T) \Rightarrow \underline{\underline{B = 244kV/m}}$.

u) What fundamental fact underlies the operation of essentially all electric motors?

A) A current-carrying conductor placed perpendicular to a magnetic field will experience a force.

B) Alternating current and direct current are both capable of doing work.

C) Iron is the only element that is magnetic.

D) A magnetic north pole carries a positive electric charge, and a magnetic south pole carries a negative electric charge.

Hint:

A current carrying loop put in a magnetic field experiences equal and opposite forces on each side of the conductor.

v) An electron and a proton enter a magnetic field perpendicularly. Both have same kinetic energy. Which of the following is true

A) Trajectory of electron is less curved B) Trajectory of proton is less curved C) Both trajectories are equally curved D) Both move on straight line path

Brief explanation.

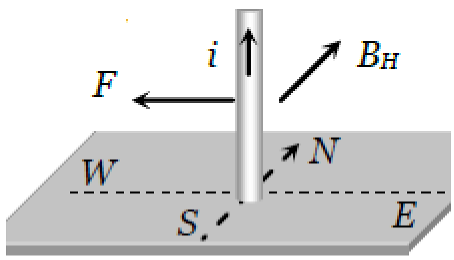
The radius of the particles path in the field is given by $r = \frac{\sqrt{2(KE)m}}{qB}$**. For the two charged particles: q is the same, KE is the same and B is the same. Therefore,** $r \sim m$**. Since mass of proton is greater than mass of electron** $\underline{\underline{r_p > r_e}}$**.**

w) A vertical wire carrying a current in the upward direction is placed in a horizontal magnetic field directed towards north. The wire will experience a force directed towards

A) North B) South C) East D) West

Brief Explanation.

By applying Right hand rule, direction of force is found towards west.



x) A coil of 50 **turns is situated in a magnetic field** $B = 0.25 weber/m^2$**. A current of** $2A$ **is flowing in the coil. The area of the coil is** $12cm$ **by** $10cm$ **Torque acting on the coil will be**

A) 0.15 N B) 0.3 N C) 0.45 N D) 0.6 N

Solution

The torque acting on a current carrying loop is $\tau = NIAB\sin\theta \Rightarrow \tau = 50(2)(120\times 10^{-4}m^2) \Rightarrow \underline{\underline{\tau = 0.3N.m}}$

Chapter 19

MAGNETISM

19.1 Main Points of the UNIT

• Magnetism describes how the atoms of a material respond to an external magnetic field. These materials a are strongly repelled by magnets.

• Diamagnetism is the property of all materials. Diamagnetism is a property of materials to oppose an applied magnetic field.

• Paramagnetic materials reinforce a magnetic field because they have unpaired electrons which will tend to align themselves in the same directions as the applied magnetic field. These are materials weekly attracted to magnets.

• Ferromagnetic materials have unpaired electrons. In addition to the tendency of these electrons to align themselves in the same direction as an applied magnetic field, they will also align themselves so that they are parallel to each other. this means that, even when the applied field is removed, the electrons in the material maintain a parallel orientation. These materials strongly attracted by external magnets.

• Circulating Molten iron at the center of the Earth's core is the cause of Earth's magnetic field.

• A moving charge sets up a a magnetic field.

• The magnetic force that acts on a charge q moving with a velocity v in a magnetic field B is $F_B = q\overrightarrow{v} \times \overrightarrow{B}$**.**

• A charged particle with mass m and charge magnitude $|q|$ moving with velocity perpendicular to a uniform magnetic field will travel in a circle of radius, period and frequency given as

$r = \frac{mv}{qB}$, $T = 2\pi\frac{m}{qB}$ and $\omega = \frac{qB}{m}$.

• In a velocity selector charged particles with a particular speed of $v = \frac{E}{B}$ are selected.

• J.J Thompson's experiment to find charge to mass ratio is based on applying equal forces from an electric and magnetic field to the charged particle. $\frac{q}{m} = \frac{E^2}{2VB^2}$.

• The magnetic force on a current carrying conductor is $F_B = IL \times B$.

• The net magnetic force acting on a current carrying loop is zero. However, the net torque acting on the loop is given as $\tau = NIAB\sin\theta$.

• A current loop creates a magnetic dipole moment given as $\mu = NIA$. Therefore,$\tau = \mu \times B$.

• The magnetic field produced by an electric current in a long straight conductor is concentric circles. It can be calculated using the equation $B = \frac{\mu_0 I}{2\pi r}$.

• parallel wires carrying current in the same direction attract each other and parallel wires carrying current in opposite direction repel each other. • Biot-Savart law is the magnetic equivalent of coulomb's law. Ampere's law is the magnetic equivalent of Gauss law.

• The magnetic field intensity $(B = \mu_0 nI)$ of a solenoid is uniform and strong inside the solenoid and weak outside.

• The magnetic field inside a conductor is $B = \mu_0\frac{Ir}{2\pi R^2}$. The magnetic field of Toroid is $B = \frac{\mu_0 NI}{2\pi r}$.

• The tangent galvanometer (TG) is an instrument for measuring the strength of an electric current in terms of the magnetic field it produces $(B_c = \frac{\mu_0 NI}{2R})$.If the TG is set such that B_c is perpendicular to the earth's magnetic field B_H, the Earth's magnetic field can be expressed as $B_H = B_E = \frac{B_C}{\tan\theta}$.

Related UEE and Additional Questions.

1) **What is the direction of the force on a negative charge that travels through a magnetic field, as shown? A) Out of the page B) Into the page**

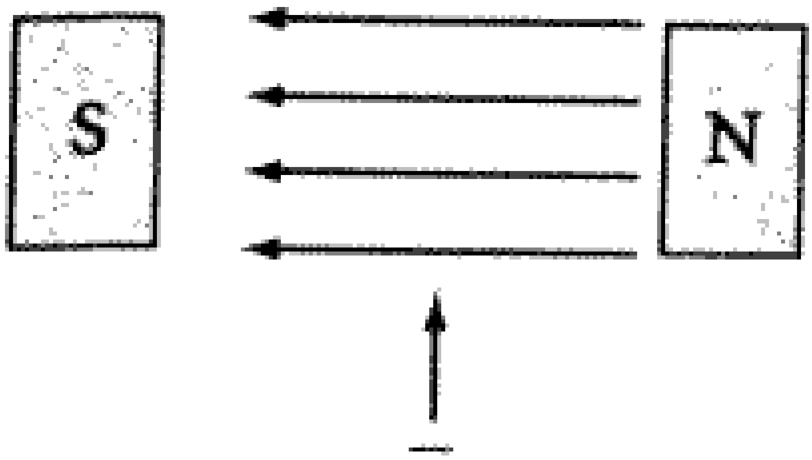


Fig. 19.1. conventions of first law

C) Upward in the plane of the page D) To the left in the plane of the page.

Brief explanation

The fingers point in the direction of motion, then curl north to south. The thumb then points in the direction of the deflecting force on a positive charge, which is opposite of the direction of the deflecting force on a negative charge. Choice B is correct.

2) **Circular paths followed by two charges q_1 and q_2 moving with the same speed in uniform magnetic field directed into the page (X) are shown in the figure below. If the two charges have the same mass which of the following is correct about the sign and the magnitude of charges? A) q_1 is positive, q_2 is negative and $|q_1| > |q_2|$.**

B) q_1 is positive, q_2 is negative and $|q_1| < |q_2|$.

C) q_1 is negative, q_2 is positive and $|q_1| > |q_2|$.

D) q_1 is negative, q_2 is positive and $|q_1| < |q_2|$.

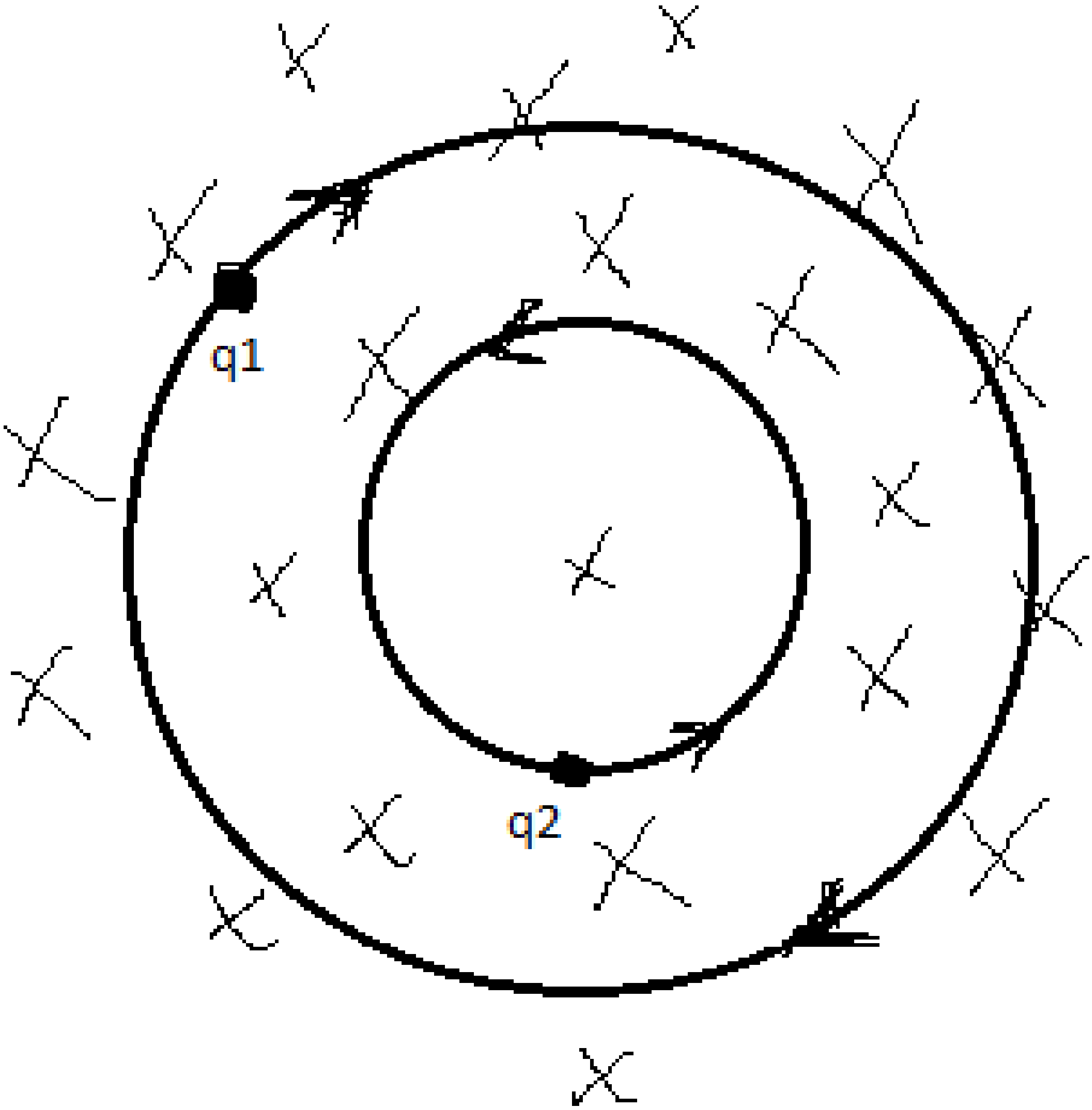


Fig. 19.2. conventions of first law

Brief solution

From the equation $r = \frac{mv}{qB}$, since the radius of q_1 is larger than the radius of q_2, then $|q_1| < |q_2|$. Applying the right hand rule the magnetic force on charge q_2 rotates the charge anticlockwise only if q_2 is positive. choice D is correct.

3) A long straight wire carries a current of 35 A. What is the magnitude of the field

B at a point 20 cm from the wire?

A) 3.5 $\times 10^{-5}$ **T** **B) 3.5** $\times 10^{-2}$ **T** **C) 7** $\times 10^{-5}$ **T** **D) 3.5** $\times 10^{-3}$ **T**

Solution

I = 35 A, r = 20 cm = 0.2 m. Magnetic field due to long straight wire is $B = \frac{\mu_0 I}{2\pi r} \Rightarrow$ $B = 3.5 \times 10^{-5} T$

4) **The direction of the force on a current carrying wire in a magnetic field is described by which of the following?**

A) perpendicular to the current only

B) perpendicular to the magnetic field only

C) perpendicular to both the current and the magnetic field

D) perpendicular to neither the current or the magnetic field

Brief solution

The force acting on a current carrying condcutor is $F_B = I\overrightarrow{L} \times \overrightarrow{B}$**. The force is perpendicular to both the current and the magnetic field.**

5) **A vertical wire carries a current straight up in a region where the magnetic field vector points due north. What is the direction of the resulting force on this current?**

A) down **B) north** **C) east** **D) west**

Hint: Use Right hand rule. choice D is correct.

6) **What is the expression of the centripetal acceleration of a particle of charge q and mass m moving in a magnetic field B on a circle of radius r if** $\overrightarrow{\mathbf{B}}$ **is perpendicular to the particles's direction of motion?**

A) $\frac{qB}{m}$ **B)** $\frac{2qB}{mr}$ **C)** $\frac{q^2B^2}{m}r$ **D)** $\frac{q^2B^2}{m^2}r$

Brief solution

$a_c = \frac{mv^2}{r}$ **and** $v = \frac{qrB}{m}$**. Therefore, substituting for v in the centripetal acceleration** $a_c = \frac{q^2B^2}{m^2}r$

7) **Two long wires of 10 m in length carries a current of 2.0 A and 0.5 A in the same direction. The wires are separated by 4.0 cm. What is the magnetic force that the wires exert on each other?**

A) 5×10^{-5} **N** **B)** 5×10^{-7} **N** $C)5 \times 10^{-6}$ **N** **D)** 4×10^{-6} **N**

Brief solution and recap

Parallel wires carrying current in the same direction attract each other.

The force exerted on each other is $F = \mu_0 \frac{I_1 I_2}{2\pi d} L = \frac{4\pi\times10^{-7}\times2\times0.5}{4\times10^{-2}\times2\pi} 10 \Rightarrow F_B = 5 \times 10^{-5} N$**.**

8) **A tangent galvanometer has 28 turns and diameter of 22 cm. when a current of 0.2 A is passed it gives a deflection of** 45^0**. What is the horizontal component of earths magnetic field?**

A) $1.6x10^{-5}$ **T** **B)** $2.6x10^{-5}$ **T** **C)** $3.2X10^{-6}T$ **D)** $3.2x10^{-3}T$

Solution

$B_H = \frac{B_C}{tan\theta} \Rightarrow B_H = B_C = \mu_0 \frac{NI}{2R} = 3.2x10^{-3}$**.**

9) **The vertical component of earths magnetic field is zero at**

A) magnetic equator **B) magnetic poles** **C) geographic poles** **D) everywhere.**

Hint:

Near the equator the angle of dip is close to zero and the vertical component of Earth's magnetic field is zero around the equator.

10) **A wire carries a current directly away from you.Which way do the magnetic field lines produced by this wire point?**

A) They point parallel to the wire in the direction of the current.

B) They point toward the wire.

C) They point away from the wire.

D) They make circles around the wire.

Brief explanation

The direction of electric fields may which point toward or away from the charge. However, the magnetic field lines always make circles around the current. Answer is choice D.

11) A thin $12cm$**long solenoid has a total of 460 turns of wire and carries a current of 2.0 A. Calculate the field inside the solenoid near the center.**

A) $9.6\times10^{-3}T$ **B)** $9.4\times10^{-3}T$ **C)** $9.6\times10^{-2}T$ **D)** $9.4\times10^{-2}T$

Solution

$B=\mu_0\frac{N}{\ell}I \Rightarrow B=\frac{4\pi\times10^{-7}(460)(2)}{0.12} \Rightarrow \underline{\underline{B=9.6\times10^{-3}T}}$

12) which one of the following statements is NOT correct about the magnetic properties of matter?

A) The unpaired electrons in the ferromagnetic materials will align with the applied magnetic field and parallel to each other.

B) The unpaired electrons in paramagnetic substance which will tend to align themselves in the same direction as the applied magnetic field.

C) There is a tendency to oppose the applied magnetic field in a diamagnetic substance.

D) The unpaired electrons in diamagnetic materials will align with the applied magnetic field and parallel to each other.

Brief recap

There are NO UNPAIRED electrons in diamagnetic materials. Choice D is not

correct.

13) **velocity selector consists of electric and magnetic fields described by the expressions $\overrightarrow{E} = E\hat{k}$ and $\overrightarrow{B} = B\hat{j}$, with $B = 15.0mT$. Find the value of E such that a $750eV$ electron moving along the positive x axis is undeflected.**

A) 122 kV/m B) 144 kV/m C) 244 kV/m D) 222 kV/m

Brief Explanation and solution

In a velocity selector charges move undeflected with a speed $v = \frac{E}{B} \Rightarrow E = vB$ and $1eV = 1.6 \times 10^{-19}J$. Another relationship is that $v = \sqrt{\frac{2KE}{m}} \Rightarrow E = \sqrt{\frac{2KE}{m}}B \Rightarrow E = \sqrt{\frac{2\times750\times1.6\times10^{-19}}{9.11\times10^{-31}}}(15 \times 10^{-3}T) \Rightarrow \underline{\underline{B = 244kV/m}}$.

14) **What fundamental fact underlies the operation of essentially all electric motors?**

A) A current-carrying conductor placed perpendicular to a magnetic field will experience a force.

B) Alternating current and direct current are both capable of doing work.

C) Iron is the only element that is magnetic.

D) A magnetic north pole carries a positive electric charge, and a magnetic south pole carries a negative electric charge.

Hint:

A current carrying loop put in a magnetic field experiences equal and opposite forces on each side of the conductor.

15) **An electron and a proton enter a magnetic field perpendicularly. Both have same kinetic energy. Which of the following is true**

A) Trajectory of electron is less curved B) Trajectory of proton is less curved C) Both trajectories are equally curved D) Both move on straight line path

Brief explanation.

The radius of the particles path in the field is given by $r = \frac{\sqrt{2(KE)m}}{qB}$. For the two charged particles: q is the same, KE is the same and B is the same. Therefore, $r \sim m$. Since mass of proton is greater than mass of electron $\underline{\underline{r_p > r_e}}$.

16) **A vertical wire carrying a current in the upward direction is placed in a horizontal magnetic field directed towards north. The wire will experience a force directed towards**

A) North **B) South** **C) East** **D) West**

Brief Explanation.

By applying Right hand rule, direction of force is found towards west.

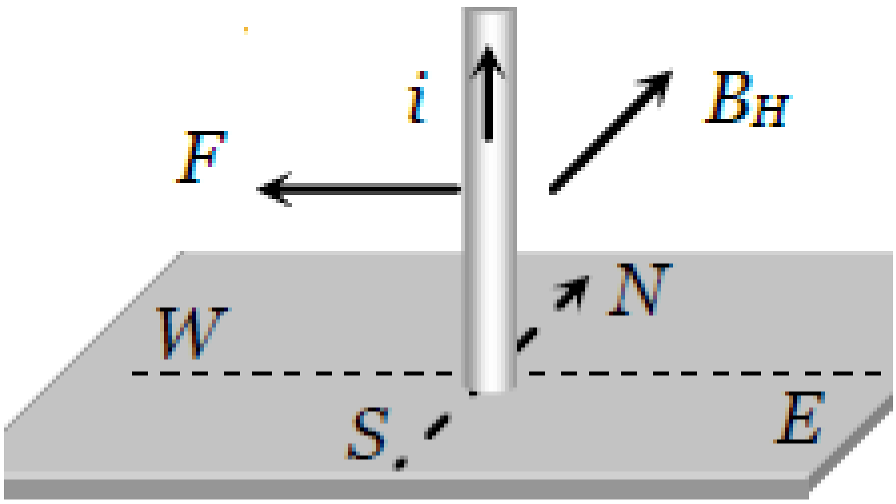


Fig. 19.3

17) **A coil of** 50 **turns is situated in a magnetic field** $B = 0.25 weber/m^2$**. A current of** $2A$ **is flowing in the coil. The area of the coil is** $12cm$ **by** $10cm$ **Torque acting on the coil will be**

A) 0.15 N **B) 0.3 N** **C) 0.45 N** **D) 0.6 N**

Solution

The torque acting on a current carrying loop is $\tau = NIAB\sin\theta \Rightarrow \tau = 50(2)(120 \times 10^{-4}m^2) \Rightarrow \underline{\underline{\tau = 0.3N.m}}$

Chapter 20

Dynamics

The Concept of Force

• There are four basic forces in nature: (1) gravitational forces between objects, (2) electromagnetic forces between electric charges, (3) strong nuclear forces between subatomic particles, and (4) weak nuclear forces that arise in certain radioactive decay processes.

• Force usually categorized into two

(1) Contact Force: This is a force that requires physical contact between two objects in order for the force to be applied. Examples: Frictional force, Tension force, Normal force, Air resistance force, and Applied force.

(2) Non-contact Force: This is a force that can act over a distance without any physical contact between the objects. Examples: Gravitational force, Magnetic force, Electrostatic force, Electromagnetic force, Nuclear force.

Basic laws of dynamics

• Newton's Law of Motion

Newton's first law: This states that " A body at rest remains at rest or, if in motion, remains in motion at constant velocity unless acted on by a net external force". This is called law of inertia. Inertia: is the tendency of the body to resist its change of state of

motion.

Newton's second law: This states that " acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass".

$$\overrightarrow{F}_{net} = m\overrightarrow{a} \tag{20.1}$$

This is often written in the more familiar form

$$\overrightarrow{F}_{net} = \Sigma\overrightarrow{F} = m\overrightarrow{a} \tag{20.2}$$

Newton's second law: component form

$$\Sigma\overrightarrow{F} = \Sigma\overrightarrow{F}_x + \Sigma\overrightarrow{F}_y + \Sigma\overrightarrow{F}_z = m(\overrightarrow{a}_x + \overrightarrow{a}_y + \overrightarrow{a}_z) \tag{20.3}$$

Newton's third law: This states that "if object A exert force on object B(an "action"), then object B exert a force on object A(a "reaction") that is equal in magnitude and opposite in direction". Action and reaction force are always:

∗ **the same in magnitude**

∗ **opposite in direction**

∗ **act on different bodies**

∗ **the same type**

∗ **always occur in pairs**

∗ **does not cancel each other**

$$\overrightarrow{F}_{AB} = -\overrightarrow{F}_{BA} \tag{20.4}$$

Friction Force

Friction force: is a force generated by two surfaces that are in contact and either at rest

or slide against each other. Its magnitude is given by

$$f = \mu F_N \tag{20.5}$$

Where μ is coefficient of friction (constant that depend on the nature of the surface in contact), F_N is normal force. There are two type of frictional force

Static friction:- friction occur when object attempt to slid over each other but not yet slid over each other. The magnitude of the maximum force of static friction given by

$$f_{s,max} = \mu_s F_N \tag{20.6}$$

where μ_s is the coefficient of static friction

$*$ static friction reaches its maximum value known as limiting friction

$*$ The magnitude of the force of static friction between any two surfaces in contact can have the values

$$f_s \leq \mu_s F_N \tag{20.7}$$

Kinetic friction:- friction force occur when object sliding over each other. Its magnitude given by

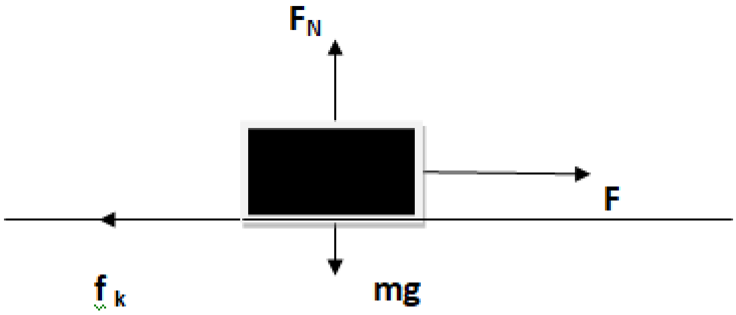
$$f_k = \mu_k F_N \tag{20.8}$$

where μ_k is the coefficient of kinetic friction

Application of Newton's Second Law of Motion

• Object is placed freely on horizontal surface

(A) pulling or pushing force parallel to the horizontal surface Normal force F_N = mg and

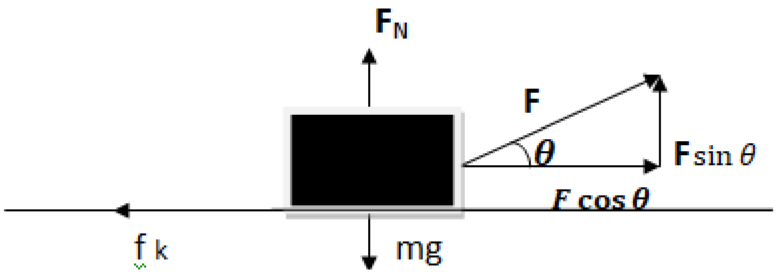


kinetic force of friction f_k = $\mu_k$mg

• The net force F - f_k = F_{net}

$$F - f_k = ma \tag{20.9}$$

(B) Pulling force F at an angle θ from the horizontal



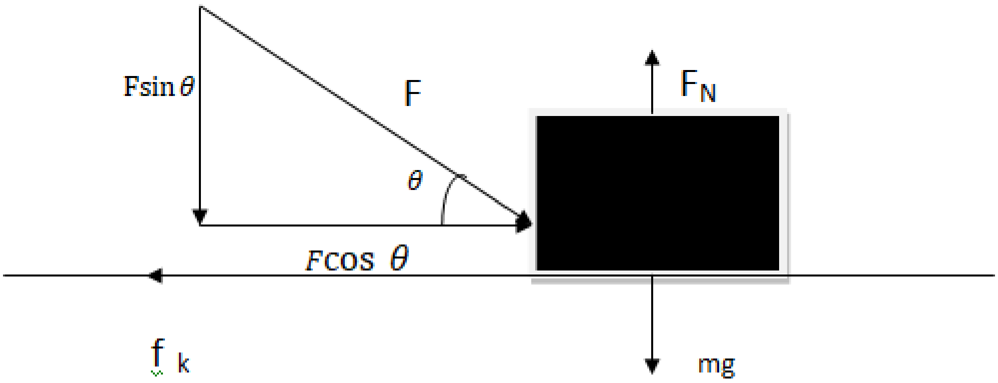
Normal force F_N = mg - F$\sin\theta$ and

kinetic force of friction f_k = $\mu_k F_N \Rightarrow f_k$ = μ_k(mg - F$\sin\theta$)

• The net force F$\cos\theta$ - f_k = F_{net}

$$F\cos\theta - f_k = ma \tag{20.10}$$

(C) Pushing force F at an angle θ from the horizontal



Normal force F_N = mg + Fsin θ and

kinetic force of friction $f_k = \mu_k F_N \Rightarrow f_k = \mu_k$(mg + Fsin θ)

• **The net force Fcos θ - $f_k = F_{net}$**

$$F\cos\theta - f_k = ma \tag{20.11}$$

Linear Momentum

The linear momentum of a particle or an object that can be modeled as a particle of mass m moving with a velocity $\overrightarrow{v}$ is defined to be the product of its mass and velocity:

$$\overrightarrow{p} = m\overrightarrow{v} \tag{20.12}$$

Linear momentum is a vector quantity, meaning it has both magnitude and direction. The direction of an object's linear momentum is the same as the direction of its velocity. Its SI unit is kg·m/s.

For an object's in three dimension

$$\overrightarrow{p} = m(v_x\hat{i} + v_y\hat{j} + v_z\hat{k}) \tag{20.13}$$

Newton's second law in terms of linear momentum "The net force (vector sum of all

forces) acting on a particle equals the time rate of change of momentum of the particle."

$$\overrightarrow{F}_{net} = m\overrightarrow{a} = \frac{m\Delta\overrightarrow{v}}{\Delta t} \Rightarrow \overrightarrow{F}_{net} = \frac{\Delta\overrightarrow{p}}{\Delta t} \quad (20.14)$$

The total linear momentum of a system of particles is defined to be the vector sum of the individual particles' linear momenta.

$$\overrightarrow{p} = m_1\overrightarrow{v}_1 + m_2\overrightarrow{v}_2 + m_3\overrightarrow{v}_3 + ---------- + m_n\overrightarrow{v}_n \quad (20.15)$$

The impulse of the force F acting on a particle is defined to be the product of the force and the time interval:

$$\overrightarrow{I} = \overrightarrow{F}\Delta t \quad (20.16)$$

The impulse of the force F acting on a particle equals the change in the momentum of the particle.

$$\overrightarrow{I} = \Delta\overrightarrow{p} \quad (20.17)$$

Conservation of Linear Momentum

law of conservation of linear momentum "If no net external force acts on a system of particles, the total linear momentum of the system cannot change(remain constant)."

$$\Sigma\overrightarrow{p}_i = \Sigma\overrightarrow{p}_f \quad (20.18)$$

$$\overrightarrow{p}_{1i} + \overrightarrow{p}_{2i} = \overrightarrow{p}_{1f} + \overrightarrow{p}_{2f}$$

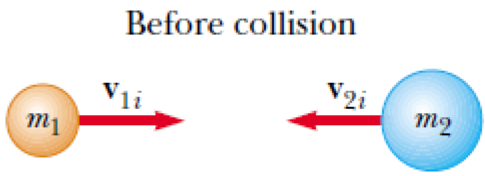
$$m_1\overrightarrow{v}_{1i} + m_2\overrightarrow{v}_{2i} = m_1\overrightarrow{v}_{1f} + m_2\overrightarrow{v}_{2f} \quad (20.19)$$

Elastic collision: is a collision in which both kinetic energy and linear momentum of the system are conserved. Perfectly elastic collisions occur between individual molecules,

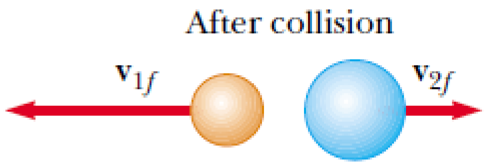
atomic and subatomic particles.

$$m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i} = m_1 \vec{v}_{1f} + m_2 \vec{v}_{2f} \tag{20.20}$$

$$\frac{1}{2} m_1 v^2{}_{1i} + \frac{1}{2} m_2 v^2{}_{2i} = \frac{1}{2} m_1 v^2{}_{1f} + \frac{1}{2} m_2 v^2{}_{2f} \tag{20.21}$$



(a)



(b)

Inelastic Collision: is a collision in which the kinetic energy of the system is not conserved, while linear momentum of the system is conserved.

$$m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i} = m_1 \vec{v}_{1f} + m_2 \vec{v}_{2f} \tag{20.22}$$

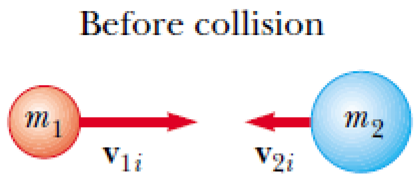
$$\frac{1}{2} m_1 v^2{}_{1i} + \frac{1}{2} m_2 v^2{}_{2i} \neq \frac{1}{2} m_1 v^2{}_{1f} + \frac{1}{2} m_2 v^2{}_{2f} \tag{20.23}$$

A collision in which a colliding objects (particles) stick together after collision is called perfectly inelastic collision(completely inelastic collision).

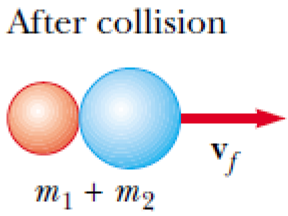
$$m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i} = (m_1 + m_2) \vec{v}_f \tag{20.24}$$

where $\vec{v}_f$ is a common velocity two bodies (particles) after collision.

- **Head-on Collisions: Collision, when objects rebound on straight line paths that co-**



(a)



(b)

incide with original direction of motion (objects moves along the same line before and after collision). These collisions can be treated one dimensional.

• Glancing Collisions: Collision in two dimension, where the objects rebound in the same plane but not necessary the same direction as the original motion.

For such two dimensional collisions, we obtain two component equations for conservation of momentum:

$$m_1 \vec{v}_{1ix} + m_2 \vec{v}_{2ix} = m_1 \vec{v}_{1fx} + m_2 \vec{v}_{2fx} \tag{20.25}$$

$$m_1 \vec{v}_{1iy} + m_2 \vec{v}_{2iy} = m_1 \vec{v}_{1fy} + m_2 \vec{v}_{2fy} \tag{20.26}$$

conservation of kinetic energy:

$$\frac{1}{2} m_1 v^2{}_{1i} + \frac{1}{2} m_2 v^2{}_{2i} = \frac{1}{2} m_1 v^2{}_{1f} + \frac{1}{2} m_2 v^2{}_{2f} \tag{20.27}$$

conservation of linear momentum:

$$m_1 \vec{v}_{1i} = m_1 \vec{v}_{1f} \cos\theta + m_2 \vec{v}_{2f} \cos\phi \tag{20.28}$$

$$0 = m_1 \vec{v}_{1f} \sin\theta - m_2 \vec{v}_{2f} \sin\phi \tag{20.29}$$

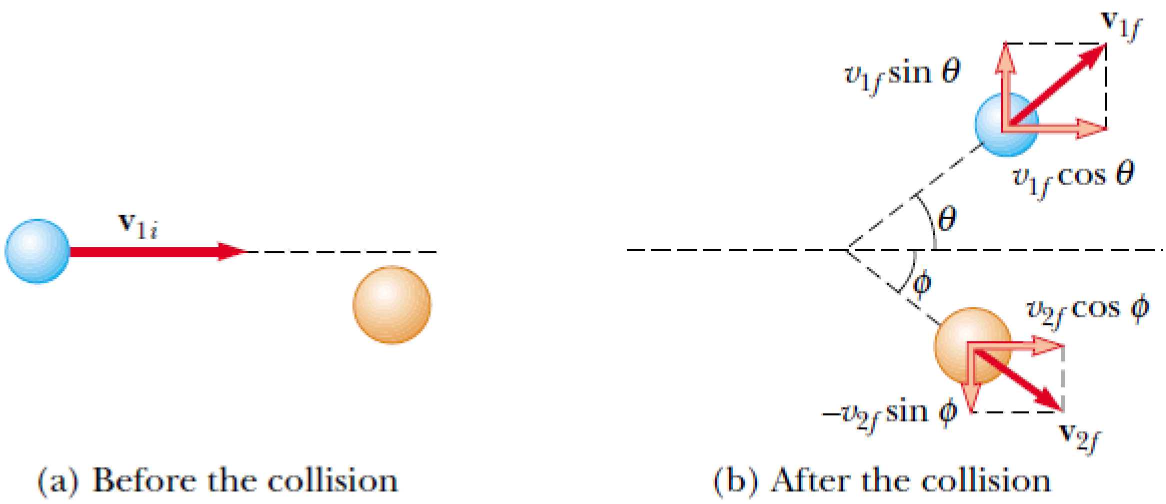


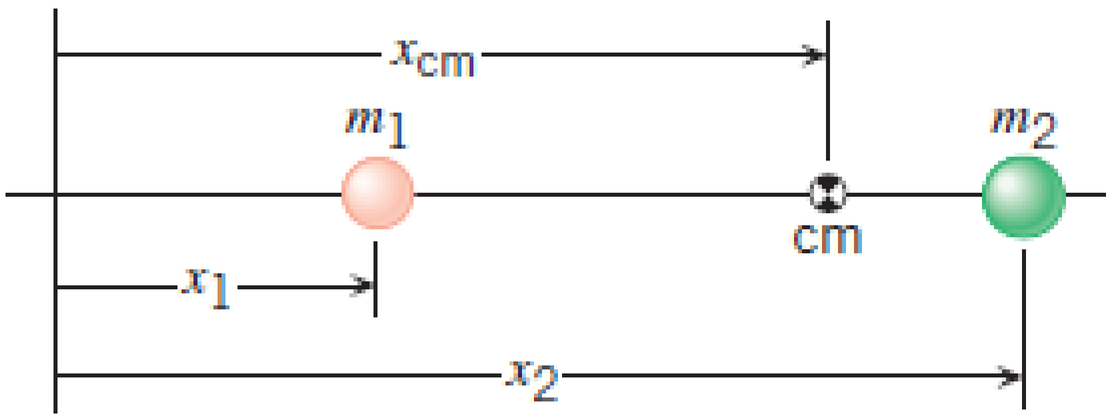
Fig. 20.1. An elastic glancing collision between two objects.

Center of Mass

• Center of mass of a body is the point in a body from which the force of gravity on that appears to be acting.

• Center of mass of a system is a single point in the system , whose translational motion is characteristics of the system as a whole when force acting or the point where whole mass of the particle system is supposed to be concentrated.

The center of mass of the pair of particles described in Figure is located on the x axis and lies somewhere between the particles. Its x coordinate is given by



$$x_{CM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} \tag{20.30}$$

• The center of mass of any system of particles in three dimensions:

The x coordinate of the center of mass is

$$x_{CM} = \frac{m_1x_1 + m_2x_2 + - - - - - - - - + m_nx_n}{m_1 + m_2 + - - - - - - - + m_n} \tag{20.31}$$

$$x_{CM} = \frac{\Sigma m_i x_i}{\Sigma m_i} \tag{20.32}$$

Similarly, the y and z coordinates of the center of mass are

$$y_{CM} = \frac{m_1y_1 + m_2y_2 + - - - - - - - - + m_ny_n}{m_1 + m_2 + - - - - - - - + m_n} \tag{20.33}$$

$$y_{CM} = \frac{\Sigma m_i y_i}{\Sigma m_i} \tag{20.34}$$

$$z_{CM} = \frac{m_1z_1 + m_2z_2 + - - - - - - - - + m_nz_n}{m_1 + m_2 + - - - - - - - + m_n} \tag{20.35}$$

$$z_{CM} = \frac{\Sigma m_i z_i}{\Sigma m_i} \tag{20.36}$$

• The position vector of the center of mass of a system of particles is defined as

$$\overrightarrow{r}_{CM} = x_{CM}\hat{i} + y_{CM}\hat{j} + z_{CM}\hat{k} \tag{20.37}$$

$$\overrightarrow{r}_{CM} = \frac{\Sigma m_i \overrightarrow{r}_i}{\Sigma m_i} \tag{20.38}$$

where is $\Sigma\, m_i$ the total mass of the system and $\overrightarrow{r}_i$ is the position vector of the i^{th} particle.

Momentum conservation in Variable-Mass Systems

• Rocket Propulsion: The operation of a rocket depends upon the law of conservation of linear momentum as applied to a system of particles, where the system is the rocket plus

its ejected fuel.

★ **The thrust on the rocket is the force exerted on it by the ejected exhaust gases. In the absence of external forces, the thrust on the rocket is given by**

$$F = Ma = v_{ex}\frac{\Delta m}{\Delta t} \tag{20.39}$$

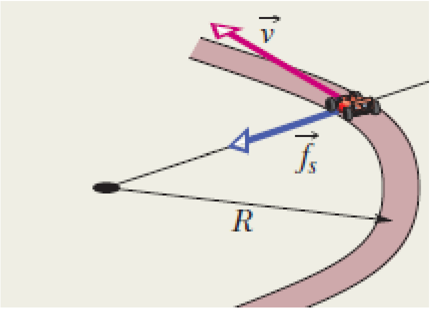
or

$$F = \frac{M\Delta v}{\Delta t} = v_{ex}\frac{\Delta m}{\Delta t} \tag{20.40}$$

where M is the rocket's instantaneous mass (including un-expended fuel), $\frac{\Delta m}{\Delta t}$ **is the rate at which the mass of the fuel burns, a is instantaneous acceleration of the rocket and** v_{ex} **is the fuel's exhaust speed relative to the rocket.**

Dynamics of uniform circular motion

Motion of car on a Level Road: When a car takes a turn on a circular path it requires centripetal force. The force that enables the car to remain in its circular path is the force of static friction between the tires of the car and the road.



$$f_{s,max} = \mathbf{m}\frac{v^2}{R}$$

$$\mu_s \mathbf{mg} = \mathbf{m}\frac{v^2}{R}$$

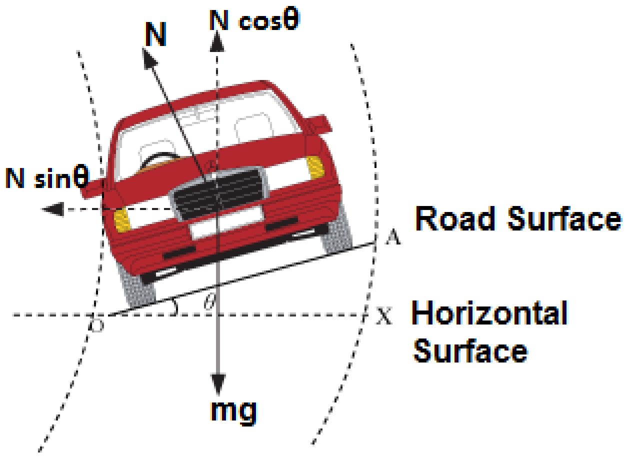
The maximum speed of the car can turn on a circular path without skidding is

$$v = \sqrt{\mu_s g R} \tag{20.41}$$

• **Note that the maximum speed does not depend on the mass of the car.**

• **Any speed greater than $\sqrt{\mu_s g R}$, the car will be skidding.**

Motion of car around a banked Road:



In the absence of friction, the maximum speed of the car without skidding is

$$v = \sqrt{Rg\tan\theta} \tag{20.42}$$

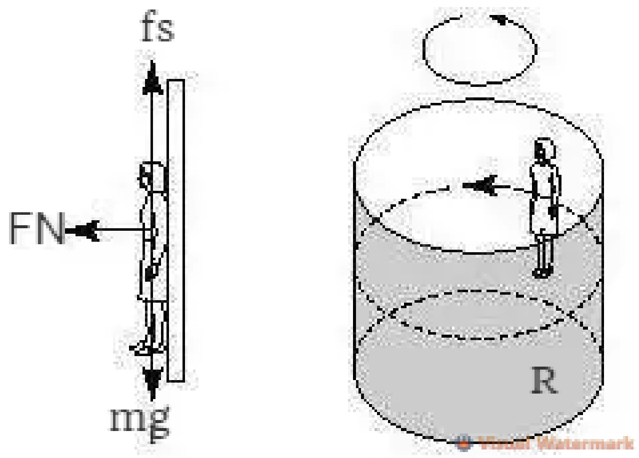
In the presence of friction, the maximum speed of the car without skidding is

$$v = \sqrt{Rg\left(\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}\right)} \tag{20.43}$$

Where θ is the banked angle

Sticking of a Person with the Wall of Rotor: A person with a mass m stands in contact against the wall of a cylindrical drum (rotor). The coefficient of static friction between the wall and the clothing is μ_s and the radius of the cylinder is R. If Rotor starts rotating

about its axis, fast enough such that any person inside is held up against the wall when the floor drops away, because friction force balances its weight in this condition.



The normal force is directed toward the center of the circle. The normal force, F_N, provides the centripetal force

$$F_N = F_c$$

The static friction force, pointing up, must equal the weight, pointing down, to keep the rider from sliding down along with the floor

$$f_s = \mathbf{mg}$$

$$f_s = \mu_s F_N \Rightarrow f_s = \mu_s F_c \tag{20.44}$$

$$mg = \mu_s m \frac{v^2}{R} \Rightarrow g = \mu_s \frac{v^2}{R} \tag{20.45}$$

The coefficient of static friction between the wall and the clothing is

$$\mu_s = \frac{Rg}{v^2} \tag{20.46}$$

Topics Related Questions on Unit

Choose the correct answer for the following Questions

1) **A warehouse worker exerts a constant horizontal force of magnitude 80 N on a 40 kg box that is initially at rest on the horizontal floor of the warehouse. When the box has moved a distance of 0.5 m, its speed is 1 m/s. What is the coefficient of kinetic friction between the box and the floor? (g = 10 m/s^2)**

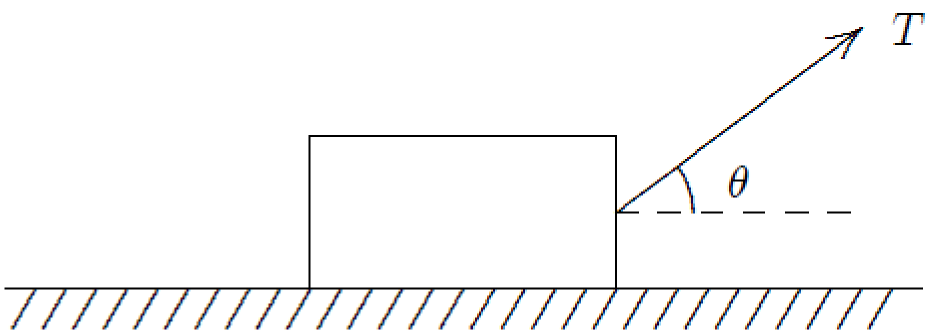
   (A) 0.25 **(B) 0.5** **(C) 0.1** **(D) 0.75**

   Solution: s = $\frac{v_f^2 - v_i^2}{2a} \Rightarrow$ a = $\frac{v_f^2 - v_i^2}{2s}$ = $\frac{1^2 - 0^2}{2(0.5)}$ = 1 m/s^2

   F - $\mu_k$mg = ma $\Rightarrow$ 80 N - μ_k(40 kg)(10 m/s^2) = (40 kg)(1 m/s^2) $\Rightarrow$ μ_k = $\frac{40}{400}$ = 0.1

   choice C is correct.

2) **A box of mass m is pulled along a surface as shown in the diagram. The pulling force of magnitude T is at an angle θ to the horizontal. The coefficient of kinetic friction between the box and the surface is μ_k. What is magnitude of the acceleration of the box?**



   (A) $\frac{T\cos\theta}{\mu_k m}$g **(B)** $\frac{T\cos\theta}{m}$ - μ_kg **(C)** $\frac{T(\cos\theta - \mu_k \sin\theta)}{m}$ - μ_kg **(D)** $\frac{T(\cos\theta + \mu_k \sin\theta)}{m}$ - μ_kg

   Solution: T$\cos\theta$ - f_k = ma, F_N = mg - T$\sin\theta$ $\Rightarrow$ f_k = μ_k(mg - T$\sin\theta$)

   T$\cos\theta$ - μ_k(mg - T$\sin\theta$) = ma $\Rightarrow$ a = $\frac{T(\cos\theta + \mu_k \sin\theta)}{m}$ - μ_kg

   choice D is correct.

3) A box of mass 100 kg is at rest on a horizontal floor. The coefficient of static friction between the box and the floor is 0.4, and the coefficient of kinetic friction is 0.3. A force F of magnitude 344 N is then applied to the box, parallel to the floor. Which of the following is true?(g = 10 m/s^2)

(A) The box will accelerate across the floor at 0.5 m/s^2.

(B) The static friction force, which is the reaction force to $\vec{F}$ as guaranteed by Newton's third law, will also have a magnitude of 344 N.

(C) The box will slide across the floor at a constant speed of 0.5 m/s.

(D) The box will not move.

Solution: m = 100 kg, μ_s = 0.4, μ_k = 0.3, F = 100 N

f_k = $\mu_k$mg = 0.3(100 kg)(10 m/s^2) = 300 N, f_s = $\mu_s$mg = 0.4(100 kg)(10 m/s^2) = 400 N $\Rightarrow f_s > f_k$, the box will not move.

choice D is correct.

4) A rope which can withstand a maximum tension of 400 N is hanging from a tree. If a monkey of mass 30 kg climbs on the rope, in which of the following cases will the rope break? (Take g = 10 m/s^2 and neglect the mass of the rope)

(A) The monkey climbs up with a uniform speed of 5 m/s.

(B) The monkey climbs up with a uniform acceleration of 2 m/s^2.

(C) The monkey climbs up with a uniform acceleration of 5 m/s^2.

(D) The monkey climbs down with a uniform acceleration of 5 m/s^2.

Solution: The rope will be break when the tension of the string is greater than 400 N

T - mg = ma $\Rightarrow$ T - (30 kg)(10 m/s^2) = (30 kg)(5 m/s^2)

T - 300 N = 150 N $\Rightarrow$ T = 300 N + 150 N = 450 N

choice C is correct.

5) As I slide a box at constant speed up a frictionless slope (inclined plane), pulling parallel to the slope, the tension in the rope will be:

(A) greater than the tension would be if the box were stationary.

(B) less than the weight of the box.

(C) equal to the weight of the box.

(D) greater than the weight of the box.

Solution: when a box moving at a constant speed along a frictionless inclined plane

T - mg$\sin\theta$ **=** F_{net}**, but a = 0,** F_{net} **= 0,** $\Rightarrow$ **T - mg**$\sin\theta$ **= 0**

T = mg$\sin\theta \Rightarrow$ **mg**$\sin\theta <$ **mg** $\Rightarrow$ **T** $<$ **mg**

choice B is correct.

6) **In an elastic collision of two objects,**

(A) momentum is not conserved.

(B) momentum is conserved, and the kinetic energy after the collision is less than its value before the collision.

(C) momentum is conserved, and the kinetic energy after the collision is the same as the kinetic energy before the collision.

(D) momentum is not conserved, and the kinetic energy of the system after the collision differs from the kinetic energy of the system before the collision.

Elastic collision is a collision in which both linear momentum and kinetic energy are conserved.

choice D is correct.

7) **A body is initially at rest and explodes into three pieces. The first piece has a mass of 1.25 kg and a velocity (30, -10) m/s, the second piece a mass of 3.25 kg and velocity of (-17, 10) m/s. The third piece has a velocity of (35.5, -40) m/s. What is the mass of the third piece?**

(A) 0.5 kg **(B) 2 kg** **(C) 3.25 kg** **(D) 1.75 kg**

Solution: For two dimensional collision the total linear momentum is conserved in each components, that is $P_{Tix} = P_{Tfx}$ **and** $P_{Tiy} = P_{Tfy}$

Total linear momentum before explosion is zero and the total linear momentum

after explosion is m_1 = 1.25 kg, v_{1f} = (30, -10) m/s, m_2 = 3.25 kg, v_{2f} = (-17, 10) m/s, v_{3f} = (35.5, -40) m/s, m_3 = ?

0 = $m_1 \vec{v}_{1fy}$ + $m_2 \vec{v}_{2fy}$ + $m_3 \vec{v}_{3fy}$

0 = (1.25 kg)(-10 m/s) + (3.25 kg)(10 m/s) + (m_3)(-40 m/s)

0 = - 12.5 kgm/s + 32.5 kgm/s - (40 m/s)(m_3) $\Rightarrow$ 0 = 20 kgm/s - (40 m/s)(m_3)

m_3 = ($\frac{20}{40}$) kg = 0.5 kg

choice A is correct.

8) **Two equal mass balls (one red and the other blue) are dropped from the same height, and rebound off the floor. The red ball rebounds to a higher position. Which ball is subjected to the greater magnitude of impulse during its collision with the floor?**

   (A) It's impossible to tell since the time intervals and forces are unknown.

   (B) Both balls were subjected to the same magnitude impulse.

   (C) the red ball

   (D) the blue ball

   Solution: In general, impulse is equal to change in momentum, which can be written as m($\vec{v}_2$ - $\vec{v}_1$), where

   m is the mass of the ball, $\vec{v}_1$ is the velocity before impact, $\vec{v}_2$ is the velocity before impact.

   The red ball experiences greater change in momentum, because

   - **Both balls have the mass m,**
   - **Both ball have the same velocity $\vec{v}_1$, as they fell from the same height,**
   - **The red ball has greater velocity $\vec{v}_2$, as it rebounded to a greater height.**

   choice C is correct.

9) **The thrust of a rocket is:**

   (A) a gravitational force acting on the rocket

   (B) the force of the exiting fuel gases on the rocket

(C) any force that is external to the rocket-fuel system

(D) a force that arises from the reduction in mass of the rocket-fuel system

thrust of a rocket is the force of the exiting fuel gases on the rocket

choice B is correct.

10) **Which one of the following forces causes the centripetal acceleration when a car negotiates a frictionless banked road?**

(A) The vertical component of the car's weight.

(B) The horizontal component of the car's weight.

(C) The horizontal component of the normal force between the car and the road.

(D) The vertical component of the normal force between the car and the road.

The horizontal component of the normal force between the car and the road provide centripetal force on the car.

choice C is correct.

11) **Near the surface of the Earth, a carnival ride consists of the riders standing against the inside wall of a cylindrical room having radius R = 4 m. The room spins about the vertical cylinder axis with angular velocity ω. Once it is up to speed, the floor of the room falls away. If the coefficient of static friction between the riders and the wall is 0.1, what is the minimum angular velocity ω (in rad/s) that will keep them from dropping with the floor? (g = 10 m/s^2)**

(A) 5 **(B) 10** **(C) 0.2** **(D) 20**

Solution: R 4 m, μ_s = 0.1, g = 10 m/s^2, $\mu_s = \frac{Rg}{v^2}$

$v^2 = \frac{Rg}{\mu_s} \Rightarrow \omega^2 R^2 = \frac{Rg}{\mu_s}$

$\omega^2 = \frac{g}{R\mu_s} = \frac{10}{(0.1)(4)} \Rightarrow \omega = \sqrt{25}$

ω = 5 rad/s

choice A is correct

Chapter 21

Work, energy and power

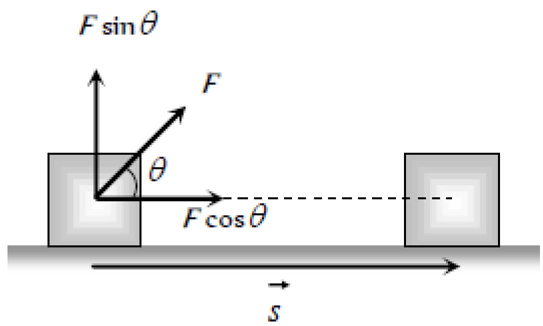
21.1 Work Done by a Constant Force

★ **Work is said to be done when a force applied on the body displaces the body through a certain distance in the direction of force.**

★ **the work W done by the constant force is defined as the product of the force magnitude F and the displacement magnitude s:**

W = Fs (Work, constant force in direction of straight-line displacement)

Let a constant force $\vec{F}$ be applied on the body such that it makes an angle θ with the horizontal and body is displaced through a distances



Since body is being displaced in the direction of $F\cos\theta$, therefore work done by the force

in displacing the body through a distance s is given

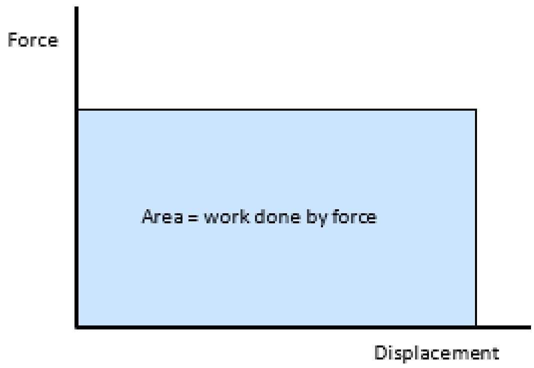
$$W = Fs\cos\theta \tag{21.1}$$

★ **work done by a force is equal to the scalar (or dot product) of the force and the displacement of the body.**

$$W = \overrightarrow{F} \cdot \overrightarrow{S} \tag{21.2}$$

★ **"Work" is transferred energy; "doing work" is the act of transferring the energy. Work has the same units as energy and is a scalar quantity.**

★ **Graphically, The rectangular area under the graph represents the work done by the constant force of magnitude F during displacement s:** ★ **Net Work done: When two or**

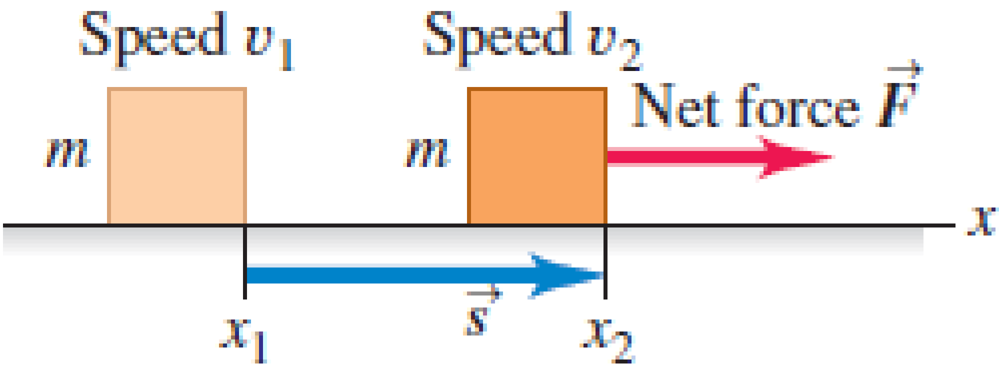


more forces act on an object, the net work done on the object is the sum of the works done by the individual forces. We can calculate the net work in two ways.

(1) We can find the work done by each force and then sum those works. (2) Alternatively, we can first find the net force of those forces. Then we can use W = Fs , substituting the magnitude F_{net} for F and also the angle between the directions of $\overrightarrow{F}_{net}$ and $\overrightarrow{s}$ for θ.

Kinetic energy and work - energy theorem

Consider a block with mass m moving to the right under the action of a constant net force with magnitude F directed to the right as shown in Figure. The block''s acceleration is constant and given by Newton''s second law F = ma. Suppose the speed changes from v_1 to v_2 while the block undergoes a displacement $\vec{s}$.



Using a constant-acceleration equation, s = $\frac{v_2^2 - v_1^2}{2a}$ $\Rightarrow$ a = $\frac{v_2^2 - v_1^2}{2s}$

So the net force F acting on the block is: F = m$\frac{v_2^2 - v_1^2}{2s}$ $\Rightarrow$ Fs = $\frac{1}{2}$mv_2^2 - $\frac{1}{2}$mv_2^1

The product Fs is the work done by the net force F and thus is equal to the net work(W_{net}) done by all the forces acting on the block.

The product half the mass 'm' and the square of the speed 'v' is defined as the kinetic energy of the body:

$$KE = \frac{1}{2}mv^2 \tag{21.3}$$

From the equation Fs = $\frac{1}{2}$mv_2^2 - $\frac{1}{2}$mv_2^1. The first term on the right side is KE_2 = $\frac{1}{2}$mv_2^2, the final kinetic energy of the block (that is, after the displacement). The second term is the initial kinetic energy, KE_1 = $\frac{1}{2}$mv_2^1, and the difference between these terms is the change in kinetic energy.

★ Work - Energy Theorem: 'The work done by the resultant(net) force 'F' in displacing

a body is equal to the change in its kinetic energy.'

$$W_{net} = \Delta KE \tag{21.4}$$

$$W_{net} = KE_2 - KE_1$$

$$W_{net} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_2^1 \tag{21.5}$$

★ **When W_{net} is positive, the kinetic energy increases (the final kinetic energy KE_2 is greater than the initial kinetic energy KE_1) and the body is going faster at the end of the displacement than at the beginning. When is W_{net} negative, the kinetic energy decreases(KE_2 is less than KE_1) and the speed is less after the displacement. When W_{net} = 0, the kinetic energy stays the same (KE_2 = KE_1) and the speed is unchanged.**

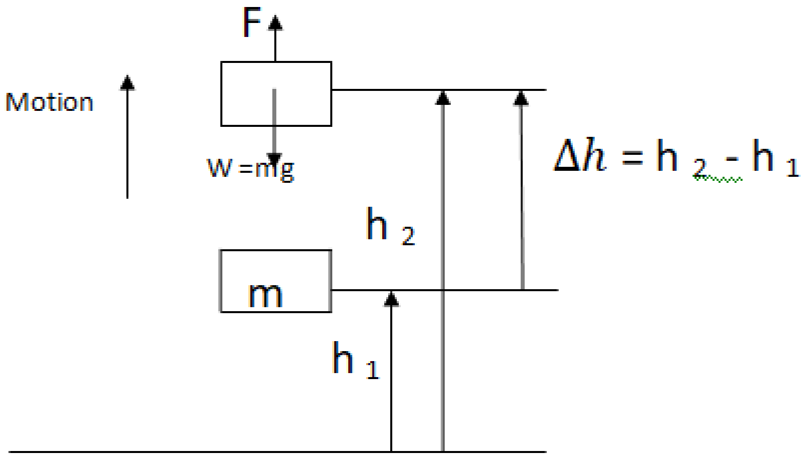
Potential Energy

Gravitational Potential Energy (U_{grav})

let's derive the expression for gravitational potential energy. Suppose a body with mass m moves along the (vertical) y-axis, as shown Figure. To find the work done by the weight when the body moves upward from an initial height h_1 above the origin to a final height h_2. The weight and displacement are in the opposite direction, so the work done on the body by its weight is negative;

$$W_{grav} = -mg\Delta h$$

$$W_{grav} = -(mgh_2 - mgh_1) \tag{21.6}$$



★ **The gravitational potential energy (U_{grav}) is defined as the product of the weight (mg) and the height (h) from some reference.**

$$U_{grav} = mgh \tag{21.7}$$

★ **The change in gravitational potential energy is**

$$\Delta U_{grav} = mgh_2 - mgh_1 \tag{21.8}$$

★ **From the equations W_{grav} = - (mgh_2 - mgh_1) and ΔU_{grav} = mgh_2 - mgh_1**

$$W_{grav} = -\Delta U_{grav} \tag{21.9}$$

★ **the work done by the gravitational force on a body of mass m is the negative of the change in the gravitational potential energy**

★ **The upward force F that lifts the object upward with constant velocity. Hence F = mg in magnitude. This force F is the same direction as the displacement. Then the work**

done by this force (W_F) is

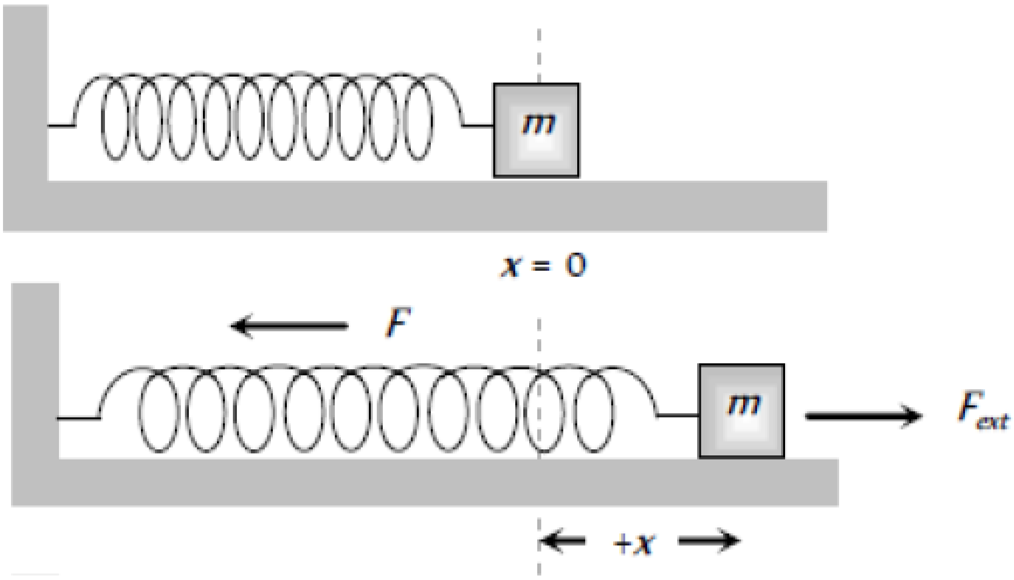
$$W_F = mgh_2 - mgh_1 \quad (21.10)$$

$$W_F = \Delta U_{grav} \quad (21.11)$$

Elastic Potential Energy

Elastic Potential Energy: stored energy in a deformable body such as a spring or rubber band. A body is called elastic if it returns to its original shape and size after being deformed.

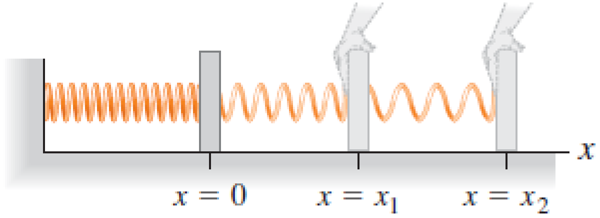
★ Consider a body of mass m that is attached to one end of a spring whose other end is held stationary as shown in Figure. When a spring is stretched from its normal position (x = 0) by a small distance x, then a restoring force is produced in the spring to bring it to the normal position.



★ The work done on the spring(work done by the external force)(W_F) in stretching the spring from zero to x is given by

$$W_F = \frac{1}{2}Kx^2 \quad (21.12)$$

★ **The work do on the spring move one end from an elongation x_1 to a different elongation x_2 is**



$$W_F = \frac{1}{2}Kx_2^2 - \frac{1}{2}Kx_1^2 \tag{21.13}$$

★ **The work done by the spring (work done by restoring force)(W_s) in stretching the spring from zero to x is given by**

$$W_s = -\frac{1}{2}Kx^2 \tag{21.14}$$

★ **The work done by the spring to move one end from an elongation x_1 to a different elongation x_2 is**

$$W_s = -(\frac{1}{2}Kx_2^2 - \frac{1}{2}Kx_1^2) \tag{21.15}$$

★ **The quantity $\frac{1}{2}$Kx^2 is define to be the elastic potential energy stored on the spring**

$$U_{el} = \frac{1}{2}Kx^2 \tag{21.16}$$

★ **The change in elastic potential energy is:**

$$\Delta U_{el} = \frac{1}{2}Kx_2^2 - \frac{1}{2}Kx_1^2 \tag{21.17}$$

★ **The work done by a spring in terms of the change in elastic potential energy:**

$$W_s = - (\frac{1}{2}\mathbf{K}x_2^2 - \frac{1}{2}\mathbf{K}x_1^2)$$

$$W_s = -\Delta U_{el} \tag{21.18}$$

★ **The work done on the spring in terms of the change in elastic potential energy:**

$$W_F = \frac{1}{2}\mathbf{K}x_2^2 - \frac{1}{2}\mathbf{K}x_1^2$$

$$W_F = \Delta U_{el} \tag{21.19}$$

Conservation of Mechanical Energy

★ **The mechanical energy ME of a system is the sum of its potential energy U and the kinetic energy KE of the objects within it:**

$$ME = U + KE \tag{21.20}$$

Where U is either gravitational potential energy or elastic potential energy or both.

★ **Conservation of mechanical energy for an isolated system 'In an isolated system, the total mechanical energy of the system remain constant'**

$$ME = KE + U = constant \tag{21.21}$$

or

$$\Delta ME = \Delta KE + \Delta U = 0 \tag{21.22}$$

$$KE_1 + U_1 = KE_2 + U_2 \tag{21.23}$$

★ **The object is falling freely with no air resistance and can be moving either up or down. Conservation of mechanical energy is**

$$\frac{1}{2}mv_1^2 + mgh_1 = \frac{1}{2}mv_2^2 + mgh_2 \tag{21.24}$$

★ **Conservation of mechanical energy of mass - spring system:**

$$\frac{1}{2}mv_1^2 + \frac{1}{2}kx_1^2 = \frac{1}{2}mv_2^2 + \frac{1}{2}kx_2^2 \tag{21.25}$$

Conservative and Non-conservative Forces

Conservative Forces

★ **A force that offers opportunity of two-way conversion between kinetic and potential energies is called a conservative force. Examples of conservative forces: the gravitational force, the spring force (restoring force), electric force and magnetic force etc.**

★ **Work done by conservative force has the following properties:**

(1) It is independent of the path followed by the object and depends on only the starting and ending points.

(2) It is zero around any closed path.

(3) It is reversible (recoverable).

(4) It can be expressed as the difference between the initial and final values of a potential-energy function.

★ **Conservative force tends to minimize potential energy within the system.**

★ **When the only forces that do work are conservative forces, the total mechanical energy ME = KE + U is constant.**

Non-Conservative Forces or dissipative force

★ **Non-Conservative Forces are forces which causes a loss of mechanical energy from the system. Examples of Non - conservative forces are friction force, applied force etc.**

★ **Work done by Non conservative force has the following properties:**

(1) It is dependent of the path followed by the object.

(2) It is not zero around any closed path.

(3) It is not reversible (recoverable).

(4) It can not be expressed as the difference between the initial and final values of a potential-energy function.

★ **From work- energy theorem**

$$W_{net} = \Delta \text{KE, but } W_{net} = W_c + W_{nc}$$

Where W_c **is work done by conservative force and** W_{nc} **is work done by Non- conservative force**

$$W_c + W_{nc} = \Delta \text{KE}, W_c = -\Delta \text{U}$$

$$-\Delta \text{U} + W_{nc} = \Delta \text{KE} \Rightarrow W_{nc} = \Delta \text{KE} + \Delta \text{U}$$

$$W_{nc} = \Delta KE + \Delta U \tag{21.26}$$

$$W_{nc} = \Delta ME \tag{21.27}$$

Power

★ **Power is the time rate at which work is done or energy transfer. Like work and energy, power is a scalar quantity.**

★ **When a quantity of work ΔW is done during a time interval Δt, the average work done per unit time or average power P_{av} is defined to be**

$$P_{av} = \frac{\Delta W}{\Delta t} \tag{21.28}$$

Topics Related Questions on Unit 5

Choose the correct answer for the following Questions

1) **A force $\overrightarrow{F}$ = 4$\hat{i}$ + c$\hat{j}$ acts on a particle as the particle goes through displacement $\overrightarrow{d}$ = (3$\hat{i}$ - 2$\hat{j}$) m. What is the value of c ,if the work done on the particle by force $\overrightarrow{F}$ is zero?**

   (A) 0 N   (B) 12 N   (C) 15 N   (D) 6 N

   solution: W = 0 ⇒ $\overrightarrow{F} \cdot \overrightarrow{d}$ = 0

   (4$\hat{i}$ + c$\hat{j}$)·(3$\hat{i}$ - 2$\hat{j}$) = 0 ⇒ 12 - 2c = 0

   2c = 12 ⇒ c = 6 N

   choice D is correct

2) **The following is a free body diagram of an object which undergoes a displacement of magnitude s along the horizontal direction. Which one of the following equations represents the total (net) work done on the object?**

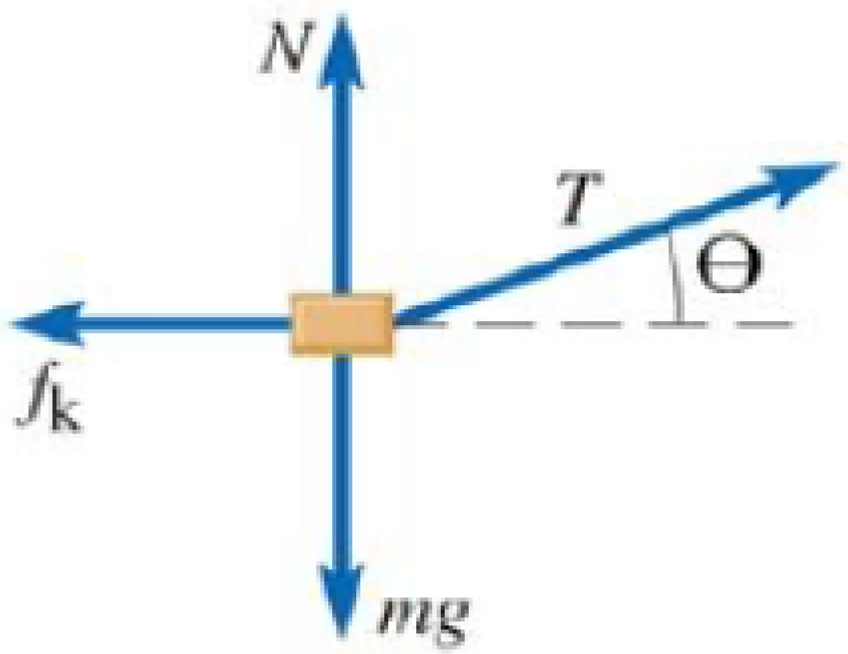
   (A) (T$\sin\theta$)s   (B) (T$\cos\theta$)s   (C) (T$\cos\theta$ - T$\sin\theta$)s   (D) (T$\cos\theta$ - f_k)s

   solution: W_{net} = W_T + W_{f_k} = (T$\cos\theta$)s + (- f_k)s

   W_{net} = (T$\cos\theta$ - f_k)s

   choice D is correct

3) **A 100 N force has a horizontal component of 80 N and a vertical component of 60 N. The force is applied to a box which rests on a level frictionless floor. The box starts from rest, and moves 2 m horizontally along the floor. What is the box's final**



kinetic energy?

(A) 160 J **(B) 200 J** **(C) 120 J** **(D) zero**

solution: F = 100 N, F_x = 80 N, F_y = 60 N, v_1 = 0 and s = 2 m

Using work-energy theorem W = ΔKE ⇒ W = KE_2 - KE_1 ⇒ W = KE_2, v_1 = 0 ⇒ KE_1 = 0

F_xs = KE_2 ⇒ KE_2 = (80 N)(2 m) = 160 J

choice A is correct

4) Two equal mass objects, A and B, are taken to the top of a tall tower. Object A is lifted straight up by a crane and object B is carried up more slowly along a stairway that encircles the tower's perimeter. Compare the change in gravitational potential energy experienced by the two objects.

(A) Object A had a greater potential energy change because it got to the top faster.

(B) Object B had a greater potential energy change because it travelled a greater distance to get to the top.

(C) Both objects experienced the same gravitational potential energy change.

(D) It is impossible to tell since times and distances are not given.

Gravitational potential energy is defined as the product of the weight (mg) and the height (h) from some reference.

Both objects have the same change in gravitational potential energy

choice C is correct

5) **Stretching a spring a distance of x requires a force of F. In the process, potential energy, U, is stored in the spring. How much force is required to stretch the spring a distance of 2x, and what potential energy is stored in the spring as a result?**

(A) 2F and 4U (B) 2F and 2U (C) F and 2U (D) 4F and 4U

solution: x_1 **= x,** F_1 **= F,** U_1 **= U,** x_2 **= 2x,** F_2 **= ?,** U_2 **= ?**

Hooke's law $F_1 = kx_1 \Rightarrow F = kx$ **and** $U_1 = \frac{1}{2}F_1x_1 \Rightarrow U_1 = \frac{1}{2}Fx$

$F_2 = kx_2 \Rightarrow F_2 = k(2x) = 2kx \Rightarrow F_2 = 2F$

$U_2 = \frac{1}{2}F_2x_2 \Rightarrow U_2 = \frac{1}{2}(2F)(2x) = 4(\frac{1}{2}Fx) \Rightarrow U_2 = 4U$

choice A is correct

6) **A truck weighs twice as much as a car, and is moving at twice the speed of the car. Which statement is true about the truck's kinetic energy compared to that of the car?**

(A) The truck has 8 times the kinetic energy of the car.

(B) All that can be said is that the truck has more kinetic energy.

(C) The truck has 4 times the kinetic energy of the car.

(D) The truck has twice the kinetic energy of the car.

solution: $W_t = 2W_c \Rightarrow m_t = 2m_c,\ v_t = 2v_c$

$KE_c = \frac{1}{2}m_cv_c^2$ **and** $KE_t = \frac{1}{2}m_tv_t^2$

$KE_t = \frac{1}{2}(2m_c)(2v_c)^2 = 8(\frac{1}{2}m_cv_c^2) = 8KE_c$

choice A is correct

7) **Two identical balls are thrown directly upward, ball A at speed v and ball B at**

speed 2v, and they feel no air resistance. Which statement about these balls is correct?

(A) Ball B will go twice as high as ball A because it had twice the initial speed.

(B) Ball B will go four times as high as ball A because it had four times the initial kinetic energy.

(C) The balls will reach the same height because they have the same mass and the same acceleration.

(D) At its highest point, ball B will have twice as much gravitational potential energy as ball A because it started out moving twice as fast.

solution: Using conservation ME for the two balls

$\frac{1}{2}\mathbf{m}v^2 = U_{grav,A}$ **and** $\frac{1}{2}\mathbf{m}(2v)^2 = U_{grav,B} \Rightarrow \mathbf{4}(\frac{1}{2}\mathbf{m}v^2) = U_{grav,B}$

$\mathbf{4}U_{grav,A} = U_{grav,B} \Rightarrow \mathbf{4mg}h_A = \mathbf{mg}h_B \Rightarrow h_B = \mathbf{4}h_A$

choice B is correct

8) **Which one of the following statements is false?**

(A) Energy stored as potential energy by a conservative force during displacement can be recovered as kinetic energy.

(B) A force is conservative if the work done by the force is dependent of the path taken.

(C) Gravity is a conservative force.

(D) If a system is acted upon only by conservative forces, then the total mechanical energy of the system is constant.

Work done by conservative force is independent of the path of the object

choice B is correct

9) **A 5 kg mass is moving horizontally at 10 m/s along a horizontal floor that can be considered frictionless. It collides with a light spring at rest. The spring compresses by 5 meters until the mass stops. What is the value of the spring constant k?**

(A) 10 N/m **(B) 15 N/m** **(C) 20 N/m** **(D) 250 N/m**

solution: m = 5 kg, v = 10 m/s, x = 5 m, k =?

When the object compressed the spring, the kinetic energy of the object will have been transferred to elastic potential energy on the spring.

$\frac{1}{2}\mathrm{m}v^2 = \frac{1}{2}\mathrm{k}x^2 \Rightarrow \mathrm{m}v^2 = \mathrm{k}x^2$

$\mathrm{k} = \frac{mv^2}{x^2} = \frac{(5)(10^2)}{5^2} = (\frac{500}{25})$ **N/m = 20 N/m**

choice C is correct

10) **A rope-way trolley of mass 1200 kg uniformly from rest to a velocity of 72 km/h in 6 s. What is the average power of the engine during this period in watt ?(Neglect friction)**

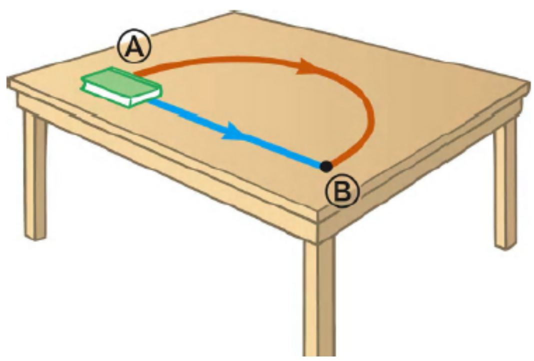
(A) 40,000 W **(B) 4000 W** **(C) 24000 W** **(D) 400 W**

solution: m = 1200 kg, $v_1 = 0$, v_2 **= 72 km/h = 72 x** $\frac{10}{36}$ **m/s = 20 m/s, Δt = 6 s**

$P_{av} = \frac{\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2}{\Delta t} = \frac{\frac{1}{2}(1200)(20^2)}{6}$ **= 40,000 W**

choice A is correct

11) **A horizontal force is used to move a book on a horizontal table from point A to point B. There is friction between the book and the table. The magnitude of work done by the force of friction when the book is moved from A to B:**



(A) is independent of the path taken.

(B) is greater for the straight path.

(C) is greater for the curved path.

(D) depends on the force that is used to move the book.

The work done by conservative force like frictional force is dependent of the path followed by the object.

choice C is correct

Chapter 22

Rotational Motion

Rotation of a Rigid Object About a Fixed Axis

$*$ A rigid object is said to be in rotational motion, if every particle on the rigid object moves in a circular path about a fixed point on a line which is called axis of rotation. A rigid object is one that is non deformable -that is, the relative locations of all particles of which the object is composed remain constant.

Rotational Variables

$*$ If a particle moves in a circular path of radius r through an angle θ (measured in radians), the arc length it moves through is

$$s = \theta r \tag{22.1}$$

$*$ The angular position of a rigid object is defined as the angle θ between a reference line attached to the object and a reference line fixed in space.

$*$ The angular displacement of a particle moving in a circular path or a rigid object rotating about a fixed axis is

$$\Delta\theta = \theta_f - \theta_i \tag{22.2}$$

where θ_i - initial angular position and θ_f - final angular position

∗ the average angular speed ω_{av} is defined as the ratio of the angular displacement of a rigid object to the time interval Δt during which the displacement occurs:

$$\omega_{av} = \frac{\Delta\theta}{\Delta t} = \frac{\theta_f - \theta_i}{t_f - t_i} \tag{22.3}$$

∗ The average angular acceleration α_{av} of a rotating rigid object is defined as the ratio of the change in the angular speed to the time interval Δt during which the change in the angular speed occurs:

$$\alpha_{av} = \frac{\Delta\omega}{\Delta t}$$

$$\alpha_{av} = \frac{\omega_f - \omega_i}{t_f - t_i} \tag{22.4}$$

∗ When a rigid object is rotating about a fixed axis, every particle on the object rotates through the same angle in a given time interval and has the same angular speed and the same angular acceleration. That is, the quantities θ, ω, and α characterize the rotational motion of the entire rigid object as well as individual particles in the object.

Rotational Motion with Constant Angular Acceleration

∗ Average angular velocity is just half the sum of the initial and final values:

$$\omega_{av} = \frac{\omega_i + \omega_f}{2} \tag{22.5}$$

∗ Angular acceleration of the rotating rigid object:

$$\alpha = \frac{\omega_f - \omega_i}{t} \tag{22.6}$$

where ω_i is the angular velocity of the rigid object at time t = 0.

$*$ **Final angular acceleration ω_f**

$$\omega_f = \omega_i + \alpha t \tag{22.7}$$

$*$ **Angular displacement of the rotating rigid object:**

$$\Delta\theta = (\frac{\omega_i + \omega_f}{2})t \tag{22.8}$$

$$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2 \tag{22.9}$$

$$\Delta\theta = \omega_f t - \frac{1}{2}\alpha t^2 \tag{22.10}$$

$$\Delta\theta = \frac{\omega_f^2 - \omega_i^2}{2\alpha} \tag{22.11}$$

$$\omega_f^2 = \omega_i^2 + 2\alpha(\Delta\theta) \tag{22.12}$$

where $\Delta\theta$ = θ_f - θ_i

$*$ **Angular displacement, angular velocity and angular acceleration is positive in the counterclockwise direction, and negative in the clockwise direction.**

$*$ **The tangential speed of a point on a rotating rigid object equals the perpendicular distance of that point from the axis of rotation multiplied by the angular speed. Therefore, although every point on the rigid object has the same angular speed,**

$$v = \omega r \tag{22.13}$$

$*$ **The angular acceleration of the rotating rigid object to the tangential acceleration at point on a rotating rigid object**

$$a_t = \alpha r \tag{22.14}$$

Torque

The torque is the turning effect of force about the axis passes away from line of action of the force. Its magnitude is equal to the product of the force and the perpendicular distance between the line of the force and the axis of rotation. It is a vector quantity and its direction can be obtained by right hand rule.

$$\tau = rF\sin\theta \tag{22.15}$$

$*$ **In vector notation**

$$\tau = \overrightarrow{r} \times \overrightarrow{F} \tag{22.16}$$

$*$ **Right-hand rule to determine the direction of torque:**

(1) Point the fingers of your right hand in the direction of $\overrightarrow{r}$.

(2) Curl your fingers toward the direction of vector $\overrightarrow{F}$.

(3) Your thumb then points in the direction of the torque,

Rotational Inertia and Rotional Kinetic Energy

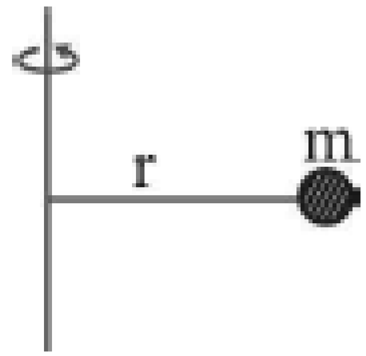
$*$ **Rotational inertia (I) is a measure of an objects resistance to changes in its speed of rotational over a certain time. Also known as Moment of inertia.**

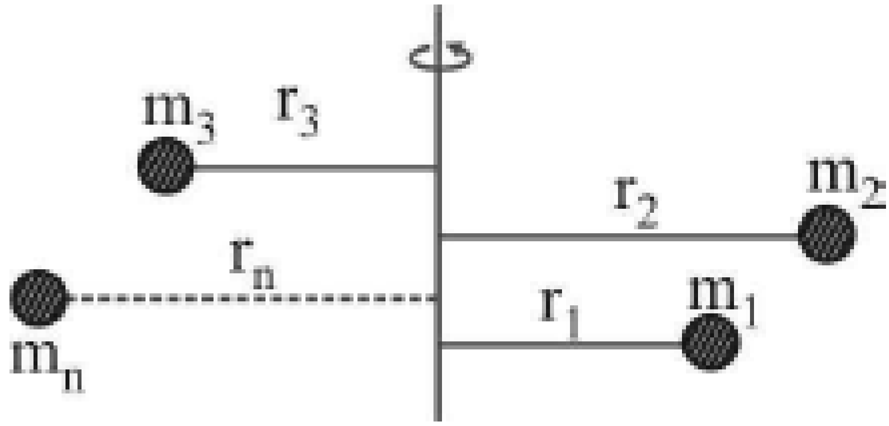
$*$ **Moment of inertia (I) of a particle of mass 'm' at a perpendicular distance 'r' from the axis of rotation is defined as**

$$I = mr^2 \tag{22.17}$$

$*$ **Moment of inertia of system of 'N' particles ($m_1 + m_2 +$ ——— $+ m_N$) at a perpendicular distance ($r_1 + r_2 +$ ——— $+ r_N$) is:**

$$I = m_1r_1^2 + m_2r_2^2 + - - - - - - - - - - - - - + m_Nr_N^2 \tag{22.18}$$





∗ The moment of inertia of a body depends on the following factors:

(i) Mass of the body.

(ii) Size and shape of the body.

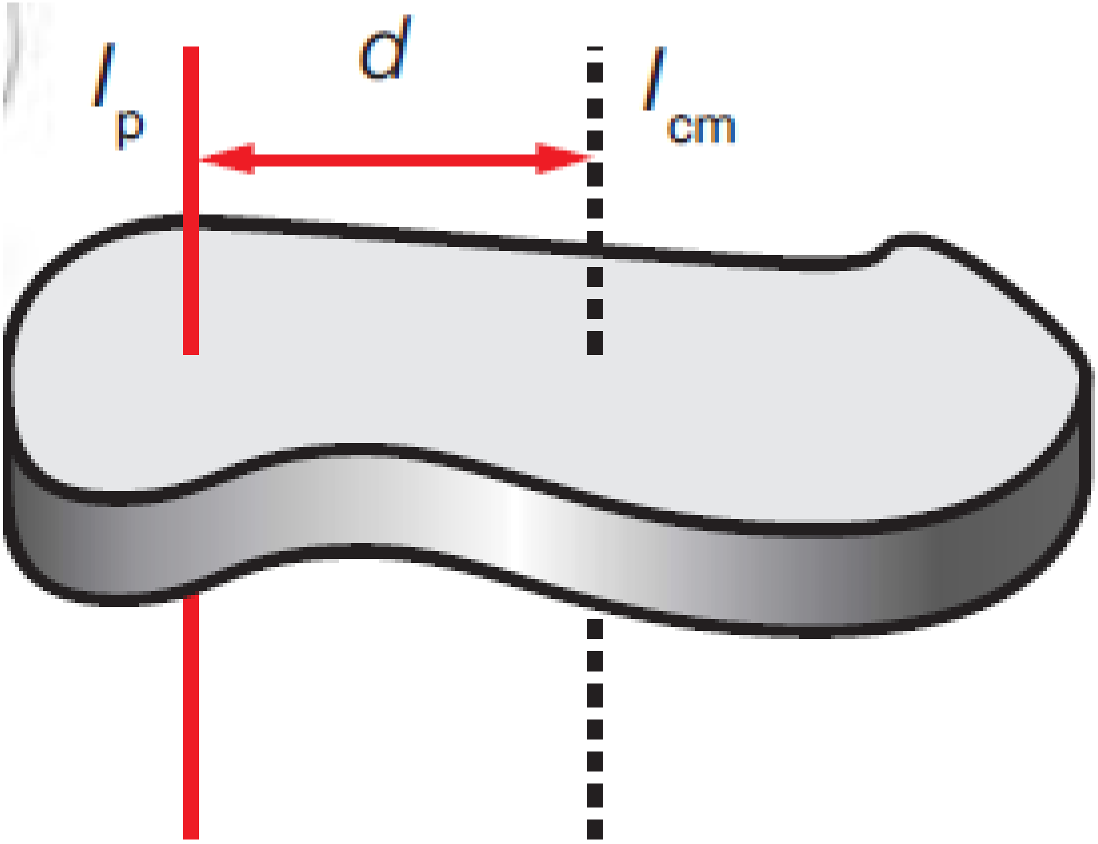
(iii) Position and orientation of axis of rotation.

∗ Moment of inertia of some regular bodies when the axis of rotation goes through the center of the body:

- **Disc or Solid cylinder I =** $\frac{1}{2}MR^2$
- **Solid sphere I =** $\frac{2}{5}MR^2$
- **Hollow sphere I =** $\frac{2}{3}MR^2$
- **Hoop or thin cylindrical shell I =** MR^2
- **Thin rod I =** $\frac{1}{12}ML^2$

∗ Parallel-axis theorem: " The moment of inertia of a rigid body about any axis is equal

to its moment of inertia about a parallel axis through its center of mass plus the product of the mass of the body and the square of the perpendicular distance between the two parallel axes."



$$I_p = I_{cm} + Md^2 \tag{22.19}$$

∗ **Newton's Second Law for Rotation: " The angular acceleration of a rotating rigid body is directly proportional to the net torque and inversely proportional to the moment of inertia of rigid body."**

$$\vec{\tau}_{net} = I\vec{\alpha} \tag{22.20}$$

∗ **If a rigid body rotates about a fixed axis with angular speed ω, its rotational kinetic energy**

is

$$KE_r = \frac{1}{2}MI^2 \qquad (22.21)$$

where I is the moment of inertia of the body around the axis of rotation.

$*$ **The total kinetic energy of a rigid body rolling on a rough surface without slipping equals the translational kinetic energy about its center of mass, $\frac{1}{2}Mv_{cm}{}^2$ plus the rotational kinetic energy of the center of mass, $\frac{1}{2}I_{cm}\omega^2$**

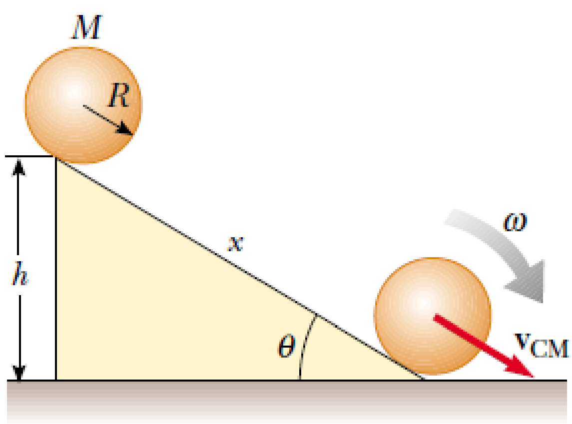
$$KE_{total} = \frac{1}{2}Mv_{cm}{}^2 + \frac{1}{2}I_{cm}\omega^2 \qquad (22.22)$$

$*$ **A system involving rotation is described by three types of energy: potential energy U, translational kinetic energy KE_t, and rotational kinetic energy KE_r. All these forms of energy must be included in the equation for conservation of mechanical energy for an isolated system:**

$$(KE_t + KE_r + U)_i = (KE_t + KE_r + U)_f \qquad (22.23)$$

where i and f refer to initial and final values, respectively.

$*$ **A sphere rolling down an incline converts potential energy to translational and rotational kinetic energy. Mgh = $\frac{1}{2}Mv_{cm}{}^2$ + $\frac{1}{2}I_{cm}\omega^2$**



Work and Power in Rotational Motion

$*$ **A torque that acts on a rigid body as it rotates about a fixed does work on that body. The work can be expressed as:**

$$W = \tau\theta \tag{22.24}$$

$*$ **The rate at which work is done by an external force in rotating a rigid body about a fixed axis, or the power delivered, is**

$$P = \tau\omega \tag{22.25}$$

$*$ **The work-kinetic energy theorem for rotational motion states that "the net work done by external forces in rotating a symmetric rigid body about a fixed axis equals the change in the body's rotational energy."**

$$W = \frac{1}{2}I{\omega_f}^2 - \frac{1}{2}I{\omega_i}^2 \tag{22.26}$$

where the angular speed changes from ω_i to ω_f.

Angular Momentum And Angular Impulse

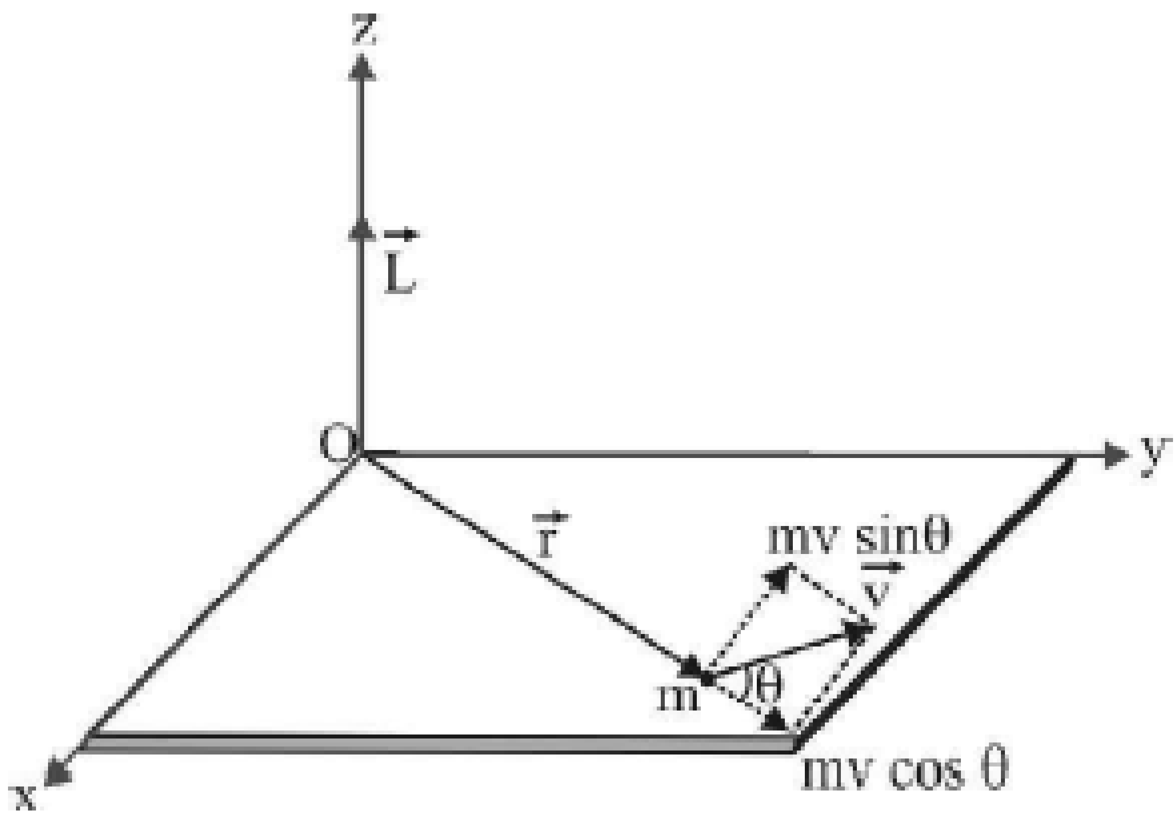
$*$ **The Angular momentum $\overrightarrow{L}$ of a particle relative to the origin O is defined by the cross product of the particle's position vector $\overrightarrow{r}$ and its linear momentum $\overrightarrow{p}$:**

$$\overrightarrow{L} = \overrightarrow{r} \times \overrightarrow{p} \tag{22.27}$$

For a particle with mass m, velocity $\overrightarrow{v}$, linear momentum $\overrightarrow{p}$ = m$\overrightarrow{v}$.

$$\overrightarrow{L} = \overrightarrow{r} \times m\overrightarrow{v} \tag{22.28}$$

$$\overrightarrow{L} = m(\overrightarrow{r} \times \overrightarrow{v}) \tag{22.29}$$



$*$ **The magnitude of the angular momentum is**

$$L = rmv\sin\theta \tag{22.30}$$

where θ is the smallest angle between $\overrightarrow{r}$ and $\overrightarrow{p}$ when these two vectors are tail to tail.

$*$ **The total angular momentum of a system of particles about some point is defined as**

the vector sum of the angular momenta of the individual particles:

$$\overrightarrow{L} = \overrightarrow{L}_1 + \overrightarrow{L}_2 + - - - - - - - - - - + \overrightarrow{L}_n \tag{22.31}$$

$*$ **The angular momentum $\overrightarrow{L}$ of a rigid body rotating about a fixed axis is is the product of its moment of inertia (I) and angular velocity ($\overrightarrow{\omega}$)**

$$\overrightarrow{L} = I\overrightarrow{\omega} \tag{22.32}$$

$*$ **Newton's second law for rotation in-terms of angular momentum: " The net torque acting on a body is equal to the time rate of change of the angular momentum of that body."**

$$\overrightarrow{\tau}_{net} = \frac{\Delta \overrightarrow{L}}{\Delta t} \tag{22.33}$$

$*$ **Angular impulse, a vector quantity, describes how torque, affects a system or body with respect to time.**

$*$ **Angular impulse is defined as the product of the torque, exerted on an object or system, over a time interval.**

$$\overrightarrow{J} = \overrightarrow{\tau}\Delta t \tag{22.34}$$

$*$ **Conservation of angular momentum: "The angular momentum of a system is constant in both magnitude and direction if the net external torque acting on the system is zero, that is, if the system is isolated."**

If τ_{net} = 0 $\Rightarrow$ $\overrightarrow{L}$ = constant

$$\overrightarrow{L}_i = \overrightarrow{L}_f \tag{22.35}$$

$$I_i \overrightarrow{\omega}_i = I_f \overrightarrow{\omega}_f \tag{22.36}$$

Topics Related Questions on Unit

Choose the correct answer for the following Questions

1) **Two wheels roll side-by-side without sliding, at the same speed (v_{cm}). The radius of wheel 2 is twice the radius of wheel 1. The angular velocity of wheel 2 is:**

   (A) twice the angular velocity of wheel 1

   (B) half the angular velocity of wheel 1

   (C) the same as the angular velocity of wheel 1

   (D) more than twice the angular velocity of wheel 1

   Solution: $v_{cm,1} = v_{cm,2}$, $r_2 = 2r_1$

   $\omega_2 = ?$

   $v_{cm,1} = v_{cm,2} \Rightarrow (\omega_1)(r_1) = (\omega_2)(r_2) \Rightarrow (\omega_1)(r_1) = (\omega_2)(2r_1)$

   $\omega_2 = \frac{1}{2}\omega_1$

   choice B is correct

2) **A wheel rotates with a constant angular acceleration of π rad/s^2. During a certain time interval its angular displacement is π rad. At the end of the interval its angular velocity is 2π rad/s. What is the angular velocity of the wheel at the beginning of this time interval?**

   (A) 2π rad/s **(B) 1 rad/s** **(C) π rad/s** **(D) $\sqrt{2}\pi$ rad/s**

   Solution: $\alpha = \pi$ rad/s^2, $\Delta\theta = \pi$ rad, $\omega_f = 2\pi$ rad/s

   $\omega_i = ?$

   $\omega_f^2 = \omega_i^2 + 2\alpha(\Delta\theta) \Rightarrow \omega_i^2 = \omega_f^2 - 2\alpha(\Delta\theta)$

   $\omega_i^2 = (2\pi rad/s)^2 - 2(\pi \text{ rad}/s^2)(\pi \text{ rad}) = 2\pi^2\ rad^2/s^2$

$\omega_i = \sqrt{2\pi^2}$ **rad/s =** $\sqrt{2}\pi$ **rad/s**

choice D is correct

3) **A rod of length L is pivoted about its left end and has a force F applied perpendicular to the other end. The force F is now removed and another force F' is applied at the midpoint of the rod. If F' is at an angle of 30^o with respect to the rod, what is its magnitude if the resulting torque is the same as when F was applied?**

(A) 4F **(B) 2F** **(C) 3F** **(D) F**

Solution: τ_1 **= LF and** $\tau_2 = \frac{L}{2}$**F'**$\sin 30^o$

F' = ?

$\tau_1 = \tau_2 \Rightarrow$ **LF =** $\frac{L}{2}$**F'**$\sin 30^o \Rightarrow$ **LF =** $\frac{L}{2}$**F'**$\frac{1}{2}$

LF = $\frac{1}{4}$**LF'** $\Rightarrow$ **F' = 4F**

choice A is correct

4) **A uniform solid sphere has a moment of inertia I about an axis tangent to its surface. What is the moment of inertia of this sphere about an axis through its center?(** $I_{cm} = \frac{2}{5}MR^2$**)**

(A) $\frac{1}{7}$**I** **(B)** $\frac{2}{7}$**I** **(C)** $\frac{2}{5}$**I** **(D)** $\frac{3}{5}$**I**

Solution: I_p **= I,** $I_{cm} = \frac{2}{5}MR^2$**, d = R**

Parallel-axis theorem $I_p = I_{cm} + Md^2 = \frac{2}{5}MR^2 + MR^2$

$I_p = \frac{7}{5}MR^2 \Rightarrow$ **I =** $\frac{7}{5}MR^2$

Take the ratio of I_p **to** I_{cm}

$\frac{I_P}{I_{cm}} = \frac{\frac{7}{5}MR^2}{\frac{2}{5}MR^2} = \frac{7}{2} \Rightarrow \frac{I}{I_{cm}} = \frac{7}{2} \Rightarrow I_{cm} = \frac{2}{7}$**I**

choice B is correct

5) **A disk with a rotational inertia of 2 kg·m^2 and a radius of 0.40 m rotates on a frictionless fixed axis perpendicular to the disk faces and through its center. A force of 5 N is applied tangentially to the rim. The angular acceleration of the disk is:**

(A) 0.40 rad/s^2 **(B) 0.60 rad/s^2** **(C) 1 rad/s^2** **(D) 2.5 rad/s^2**

Solution: R = 0.40 m, I = 2 kg·m^2, F = 5 N

α **= ?**

From Newton's second law for rotation τ = Iα and torque in terms of F and R, τ = RF

Iα = RF $\Rightarrow \alpha = \frac{RF}{I} = \frac{(0.40m)(5N)}{2kg \cdot m^2}$

α **= 1 rad/s^2**

choice C is correct

6) **The moment of inertia of a body about a given axis is 1.2 kg·m^2. Initially the body is at rest. In order to produce a rotating kinetic energy of 1500 J, an angular acceleration of 25 rad/s^2 must be applied about that axis for duration of**

(A) 4 sec. (B) 2 sec. (C) 8 sec. (D) 10 sec.

Solution: I = 1.2 kg·m^2, ω_i = 0, $KE_{r,i}$ = 0, $KE_{r,f}$ = 1500 J and α = 25 rad/s^2

t = ?

$KE_{r,f} = \frac{1}{2}\text{I}\omega_f \Rightarrow \omega_f = \sqrt{\frac{2KE_{r,f}}{I}}$

$\omega_f = \sqrt{\frac{2(1500J)}{1.2kg \cdot m^2}}$ **= 50 rad/s**

$\alpha = \frac{\omega_f - \omega_i}{t} \Rightarrow \alpha = \frac{\omega_f}{t} \Rightarrow$ **t** $= \frac{\omega_f}{\alpha} = \frac{50rad/s}{25rad/s^2}$ **= 2 s**

choice B is correct

7) **If the angular momentum of a system about a fixed point P is constant, which one of the following statements must be TRUE?**

(A) No torque about P acts on any part of the system.

(B) A constant torque about P acts on each part of the system.

(C) A constant external torque about P acts on the system.

(D) Zero net external torque about P acts on the system.

From conservation angular momentum, if the net external torque acting on system about a given axis of rotation is zero then the angular momentum of the system is constant

choice D is correct

8) **A solid sphere of mass 1 kg and radius 0.010 m starts from rest and rolls without slipping down a 7-m high inclined plane. What is the speed of the sphere when it reaches the bottom of the inclined plane? (g = 10 m/s^2, I_{cm} = $\frac{2}{5}$MR^2)**

(A) 10 m/s **(B) 5 m/s** **(C) 1.3 m/s** **(D) 6.3 m/s**

Solution: A sphere rolling down an incline converts potential energy to translational and rotational kinetic energy.

Mgh = $\frac{1}{2}$M${v_{cm}}^2$ + $\frac{1}{2}I_{cm}\omega^2$, I_{cm} = $\frac{2}{5}$MR^2 and $\omega = \frac{v_{cm}}{R}$

Mgh = $\frac{1}{2}$M${v_{cm}}^2$ + $\frac{1}{2}(\frac{2}{5}$M$R^2)(\frac{v_{cm}}{R}) \Rightarrow$ Mgh = $\frac{1}{2}$M${v_{cm}}^2$ + $\frac{1}{5}$M${v_{cm}}^2$

Mgh = $\frac{7}{10}$M${v_{cm}}^2 \Rightarrow v_{cm} = \sqrt{\frac{10}{7}gh} = \sqrt{\frac{10}{7}(10m/s^2)(7m)}$ = 10 m/s

choice A is correct

9) **A 500 g particle is located at the point $\vec{r}$ = (4$\hat{i}$ + 3$\hat{j}$ - 2$\hat{k}$) m and is moving with a velocity $\vec{v}$ = (5$\hat{i}$ - 2$\hat{j}$ + 4$\hat{k}$) m/s . What is the angular momentum of this particle about the origin?**

(A) (24$\hat{i}$ - 6$\hat{j}$ - 8$\hat{k}$) kg·m^2/s

(B) (12$\hat{i}$ - 3$\hat{j}$ - 4$\hat{k}$) kg·m^2/s

(C) (8$\hat{i}$ + 14$\hat{j}$ - 13$\hat{k}$) kg·m^2/s

(D) (4$\hat{i}$ - 13$\hat{j}$ - 11.5$\hat{k}$) kg·m^2/s

Solution: m = 500 g = 0.5 kg, $\vec{r}$ = (4$\hat{i}$ + 3$\hat{j}$ - 2$\hat{k}$) m, $\vec{v}$ = (5$\hat{i}$ - 2$\hat{j}$ + 4$\hat{k}$) m/s

$\vec{L}$ = ?

$\vec{L}$ = m($\vec{r} \times \vec{v}$)

$\vec{L}$ = 0.5 kg((4$\hat{i}$ + 3$\hat{j}$ - 2$\hat{k}$) $\times$ (5$\hat{i}$ - 2$\hat{j}$ + 4$\hat{k}$)) m^2/s

$\vec{L}$ = (4$\hat{i}$ - 13$\hat{j}$ - 11.5$\hat{k}$) kg·m^2/s

choice D is correct

10) **A spinning top is spun at an angular velocity of 3 rad/s, by applying a torque of 10 Nm. How much power is being transferred to the spinning top?**

(A)30 W **(B) 3.33 W** **(C) 300 W** **(D) 40 W**

Solution: ω = 3 rad/s, τ = 10 Nm

P = ?

P = $\tau\omega$ = (10 Nm)(3 rad/s) = 30 W

choice A is correct

Chapter 23

Equilibrium

Equilibrium of a particle

∗ Newton's first law of motion states that a particle will continue in its of uniform motion along straight line or rest unless it acted on by a force. We can restate Newton's first law to give the equilibrium of a particle, which is that in the absence of net external force a particle is said to be in equilibrium.

∗ Force acting on a particle produce translational motion but not rotational motion.

∗ First condition of equilibrium: "If a particle is said to be in equilibrium, the vector sum of all forces acting on the particle is zero."

$$\Sigma\overrightarrow{F} = 0 \tag{23.1}$$

or

$$\Sigma F_x = 0 \quad and \quad \Sigma F_y = 0 \tag{23.2}$$

∗ Coplanar forces are forces whose lines of action are confined to one plane.

∗ Concurrent forces are forces whose lines of action pass through a common point.

∗ A moment of a force, or a torque, is a measure of a force's tendency to cause a body to rotate. The moment depends on both the force, and on the position at which the force acts

Conditions for Equilibrium

∗ **The two necessary conditions for equilibrium of an object are:**

1. The vector sum of all the external forces (resultant external force) that act on the body must be zero.

$$\Sigma\overrightarrow{F} = 0 \tag{23.3}$$

2. The vector sum of all external torques (resultant external torque) that act on the body, measured about any possible point (axis), must be zero.

$$\Sigma\overrightarrow{\tau} = 0 \tag{23.4}$$

Alternatively the second condition of equilibrium:

The sum of clockwise torques must be equal to the sum of anticlockwise torques.

$$(\Sigma\tau)_{clockwise} = (\Sigma\tau)_{anticlockwise} \tag{23.5}$$

The first condition is the condition for translational equilibrium, and the second is the condition for rotational equilibrium.

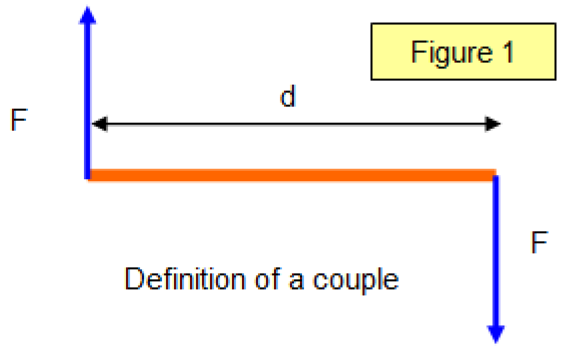
∗ **Static equilibrium is a type of equilibrium that occurs when a body is at rest and there is no net force and net torque acting on it.**

∗ **Dynamic equilibrium is a type of equilibrium that occurs when a body is moving at a constant velocity and there is no net force and net torque acting on it.**

Couple

∗ **Couple is a pair of forces with equal magnitude but opposite directions, which produce rotation, but not translatonal motion of a body.**

∗ **Examples of couple:**



(1) Steering wheel of a car.

(2) Turning of a screw driver.

(3) Opening and closing of water tap.

$*$ **A couple does not satisfy second condition of equilibrium.**

$*$ **The magnitude of the torque of a couple is the product of the magnitude of one of the force and perpendicular distance between the lines of action of the two forces.**

$$\tau = Fd \tag{23.6}$$

$*$ **The properties of a couple are:**

1. The algebraic sum of the forces consisting the couple is zero

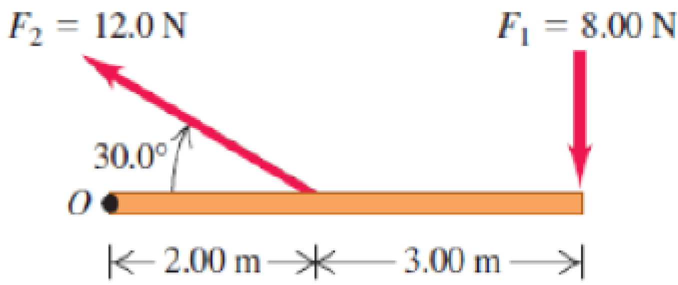
2. The moment of a couple (torque) is not zero and has the same magnitude irrespective of the perpendicular axis chosen.

Topics Related Questions on Unit

Choose the correct answer for the following Questions

1) **What is the net torque about point O for the two forces applied as in figure. The rod and both forces are in the plane of the page?** ($\sin 30^o$ **= 0.5,** $\cos 30^o$ **= 0.866**)

   (A) -28 Nm **(B) 12 Nm** **(C) -40 Nm** **(D) 68 Nm**



Solution: r_1 **= 5 m,** r_2 **= 2 m,** F_1 **= 8 N and** F_2 **= 12 N**

$\vec{\tau}_{clockwise}$ **= -** $F_1 r_1$ **= - (8 N)(5 m) = - 40 Nm and**

$\vec{\tau}_{anticlockwise}$ **=** $(F_2 \sin 30^o)(r_2)$ **= (12 N)(0.5)(2 m) = 12 Nm**

The net torque about point O is:

$\vec{\tau}_{net} = \vec{\tau}_{clockwise} + \vec{\tau}_{anticlockwise}$ **= - 40 Nm + 12 Nm = - 28 Nm**

choice A is correct

2) For a body to be in equilibrium under the combined action of several forces:

(A) all the forces must be applied at the same point

(B) all of the forces form pairs of equal and opposite forces

(C) any two of these forces must be balanced by a third force

(D) the sum of the torques about any point must equal zero

Second condition of equilibrium: " The vector sum of all external torques (resultant external torque) that act on the body, measured about any possible point (axis), must be zero."

choice D is correct

3) n statics, a couple is defined as ________ separated by a perpendicular distance.

(A) two forces in the same direction.

(B) two forces of equal magnitude.

(C) two forces of equal magnitude acting in opposite directions.

(D) two forces of equal magnitude acting in the same direction.

Couple is a pair of forces with equal magnitude but opposite directions, which

produce rotation, but not translatonal motion of a body.

choice C is correct

Chapter 24

Properties of Bulk Matter

Review and Summary

Elastic behaviour

∗ Elastic deformation is deformation where the object will return to its original shape when the force is removed.

∗ Plastic deformation is deformation where the object will not return to its original shape when the force is removed.

∗ The four main types of deformation are:

(1) Tension deformation (3) Shear deformation

(2) Torsional deformation (4) compressional deformation

Stress - Strain relation

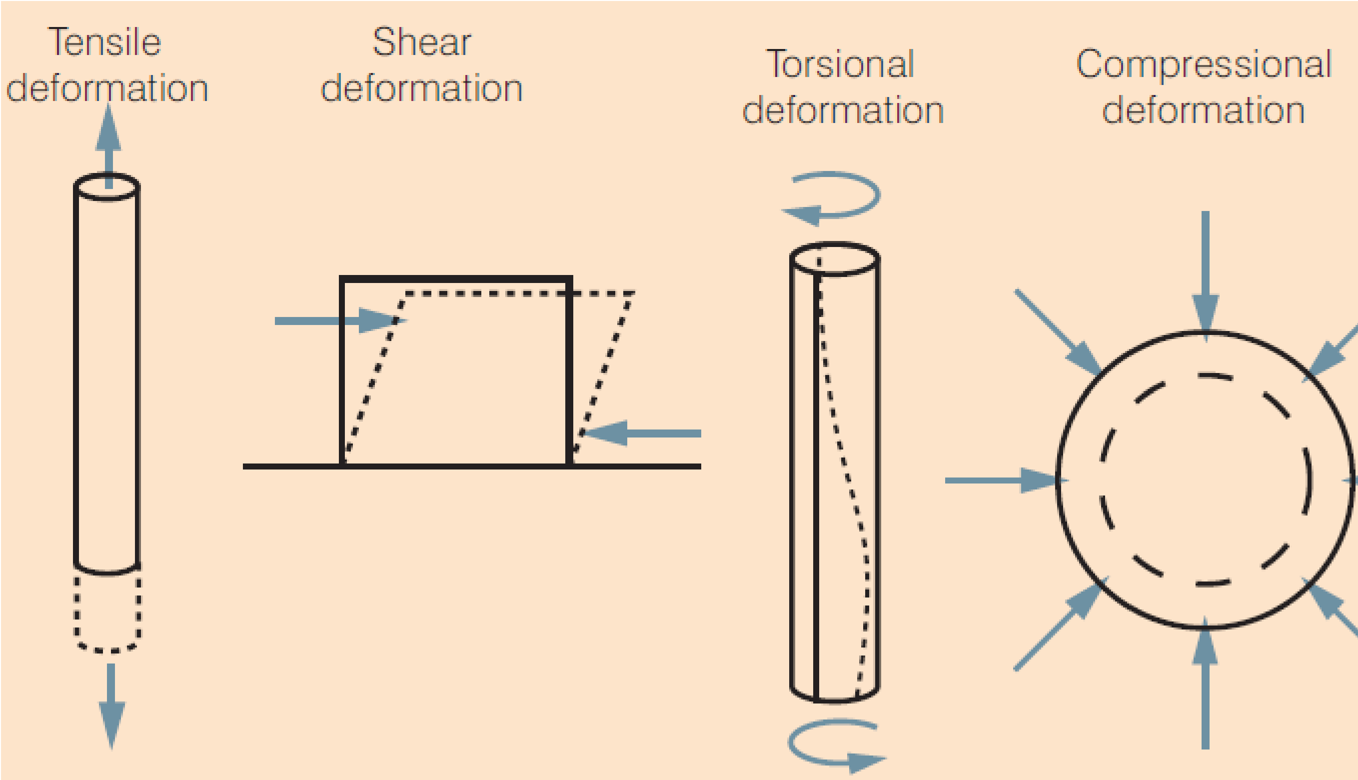
∗ Stress is a quantity that is proportional to the force causing a deformation; more specifically, stress is the external force acting on an object per unit cross-sectional area. The result of a stress is strain, which is a measure of the degree of deformation.

∗ Tensile stress is tensile force F divided by the cross-sectional area A.

$$\text{Tensile stress} = \frac{F_\perp}{A}$$

The subscript $\perp$ is a reminder that the forces act perpendicular to the cross section.

∗ The tensile strain of the object equals the fractional change in length, which is the ratio



of the elongation (extension) ΔL to the original length L_o

$$\textbf{Tensile strain} = \frac{\Delta L}{L_o} = \frac{L - L_o}{L_o}$$

∗ **Young's modulus, which measures the resistance of a solid to a change in its length.**

∗ **Young's modulus is defined as the ratio of tensile stress to tensile strain up to the material's limit of proportionality. In symbol:**

$$Y = \frac{F_{\perp}/A}{\Delta L/L_o} = \frac{F_{\perp} L_o}{A \Delta L} \tag{24.1}$$

Young's modulus is typically used to characterize a rod or wire stressed under either tension or compression.

∗ **Bulk modulus, which measures the resistance of solids or liquids to changes in their volume when under increasing pressure from all sides.**

∗ bulk modulus is defined as the ratio of volume stress to volume strain. In symbol

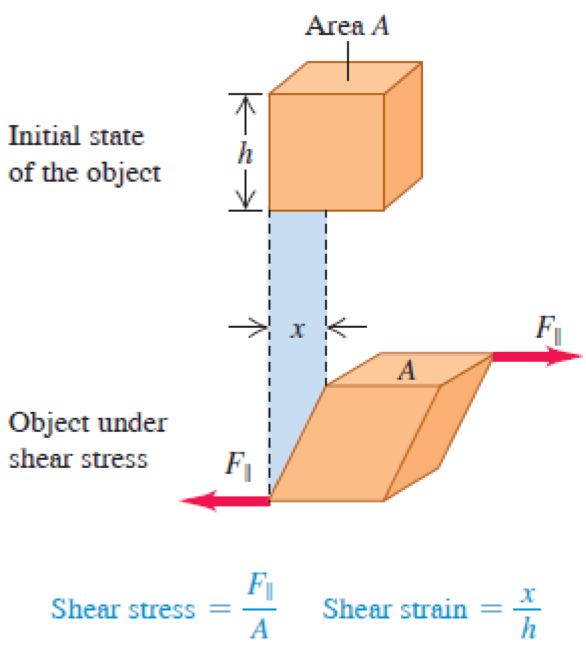
$$B = -\frac{\Delta F/A}{\Delta V/V_o} \tag{24.2}$$

$$B = -\frac{\Delta P}{\Delta V/V_o} \tag{24.3}$$

A negative sign is inserted in this defining equation so that B is a positive number. This maneuver is necessary because an increase in pressure (positive ΔP) causes a decrease in volume (negative ΔV) and vice versa.

∗ Shear modulus, which measures the resistance to motion of the planes within a solid parallel to each other.

Shear modulus = $\frac{Shearstress}{Shearstrain}$



∗ Shear stress define as the force $F_{\|}$ acting tangent to the surface divided by the area A on which it acts:

Shear stress = $\frac{F_{\parallel}}{A}$

$*$ **Shear strain define as the ratio of the horizontal distance that the sheared face moves (x) to the height of the object (h):**

Shear strain = $\frac{x}{h}$

$*$ **Shear modulus S is**

$$S = \frac{F_{\parallel}/A}{x/h} = \frac{F_{\parallel}h}{Ax} \tag{24.4}$$

$*$ **Strain Energy is the elastic potential energy gained by a wire during elongation (extension) with tensile force. For linearly elastic material strain energy is**

$$Strainenergy = \frac{1}{2}Fx \tag{24.5}$$

Fluid Statics

$*$ **If F is the magnitude of a force exerted perpendicular to a given surface of area A, then the pressure P is the force divided by the area:**

$$P = \frac{F}{A} \tag{24.6}$$

$*$ **Pressure exerted on a closed fluid column (container) at the depth h below the surface of the fluid is given by**

$$P = \rho gh \tag{24.7}$$

Pressure due to a closed fluid column depends only the depth of the fluid (h), the density

of the fluid (ρ), and the acceleration due to gravity (g). i.e It does not depend on the shape of the (column) container.

∗ The total pressure (absolute pressure) P at the depth h below the surface of the fluid open to the atmosphere is

$$P = P_{atm} + \rho g h \tag{24.8}$$

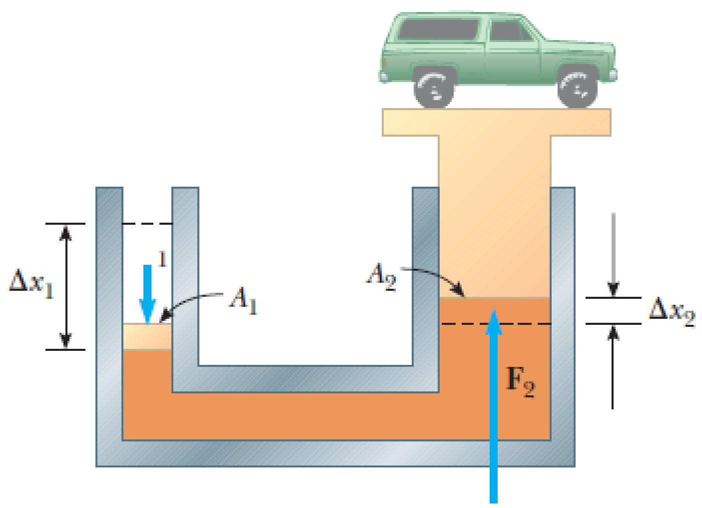
where P_{atm} is the atmosphere pressure (1 atm = 101 kpa = 1.01 x 10^5 pa)

∗ Absolute pressure is the actual pressure at a given point, that is, it is a pressure exerted at a point by a fluid including atmospheric pressure.

∗ Gauge pressure is the difference between absolute pressure and atmospheric pressure.

∗ Pascal's principle:: "Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing container."

An important application of Pascal's principle is the hydraulic press as shown in figure A force of magnitude F_1 is applied to a small piston of surface area A_1. The pressure



is transmitted through an incompressible liquid to a larger piston of surface area A_2. Because the pressure must be the same on both sides, so

$$\mathbf{P} = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \tag{24.9}$$

* **Archimedes' Principle: "When an object is completely or partially immersed in a fluid, the fluid exerts an upward force (buoyant force) on the object equal to the weight of the fluid displaced by the object."**

$$F_b = W_f \tag{24.10}$$

where W_f is the weight of the fluid displaced by the object.

* **Buoyant force is the upward force exerted by a fluid on any immersed object.**

* **The buoyant force is exerted by the fluid. It is not determined by properties of the object, except for the amount of fluid displaced by the object. Thus, if several objects of different densities but the same volume are immersed in a fluid, they will all experience the same buoyant force. Whether they sink or float will be determined by the relationship between the buoyant force and the weight of the fluid displaced.**

* **Buoyant force F_b in terms of density of fluid ρ_f, the volume of the fluid displaced by the object V_f, and acceleration due to gravity g is given by**

$$F_b = \rho_f V_f g \tag{24.11}$$

* **The buoyant force depends on the fluid density. The buoyant force on an object is proportional to the density of the fluid in which the object is immersed, not the density of the object. If a wooden block and an iron block have the same volume and both are submerged in water, both experience the same buoyant force. The wooden block rises and the iron block sinks because this buoyant force is greater than the weight of the wooden block but less than the weight of the iron block.**

* **The buoyant force in terms of actual weight of the object (weight of the object in air)**

and apparent weight of the object (weight of the object in fluid) is given by

$$F_b = W_{air} - W_{app} \tag{24.12}$$

$*$ **Fractional submerged volume of a floating body: When density of the object (ρ_{object}) is less than the density of the fluid (ρ_{fluid}), the object floats partially submerged. If V_{object} is the volume of the object and V_{fluid} is the volume of the fluid displaced by the object (this volume is the same as the volume of that part of the object that is beneath the surface of the fluid), then for a floating body**

$$\frac{V_{fluid}}{V_{object}} = \frac{\rho_{object}}{\rho_{fluid}} \tag{24.13}$$

This equation tells us that the fraction of the volume of a floating object that is below the fluid surface is equal to the ratio of the density of the object to that of the fluid.

$*$ **The fraction of the volume of a floating object above the surface of the fluid is**

$$\frac{V_{above}}{V_{object}} = 1 - \frac{\rho_{object}}{\rho_{fluid}} \tag{24.14}$$

where V_{above} is the volume of the object above the surface of the fluid.

$*$ **Surface Tension is defined as a cohesive effect at the surface of the liquid due to the forces between the liquid's atoms or molecules.**

$*$ **Mathematically surface tension of liquid is the force acting on a unit length of an imaginary line drawn on free surface of the liquid. Thus if F be the force acting on l length of the line, then surface tension**

Surface tension = $\frac{Force}{length}$

$$f = \frac{F}{l} \tag{24.15}$$

∗ Surface tension is a property of a liquid's surface that causes it to act like a stretched elastic skin; it is caused by the forces of attraction between the particles of the liquid and the other substances with which it comes into contact.

∗ Surface tension of liquid dependent of the

(A) temperature of the liquid

(B) nature of the liquid

(C) impurities present in the liquid

∗ When there is no external forces, the shape of a liquid drop is determined by surface tension

∗ Surface Energy is a measure of the disruption of inter-molecular bonds caused by a surface.

∗ Angle of contact is the angle at which a liquid surface meets a solid surface.

(i) Angle of contact is the property of the materials in contact.

(ii) It decreases with the increase in temperature.

(iii) It decreases with the addition of soluble impurities, like soap, detergent etc.

∗ Capillary Action: The movement of a liquid along the surface of a solid caused by the attraction of molecules of the solid.

∗ Meniscus is a curve in the surface of a liquid caused by the relative attraction of the liquid molecules to the solid surfaces of the container.

∗ To find the height h of a liquid column caused as a result of capillary action is given by

$$h = \frac{2f\cos\theta}{\rho g r} \tag{24.16}$$

where f is the liquid air surface tension, θ is the contact angle, ρ is the density of liquid, g is acceleration due to gravity and r is radius of tube.

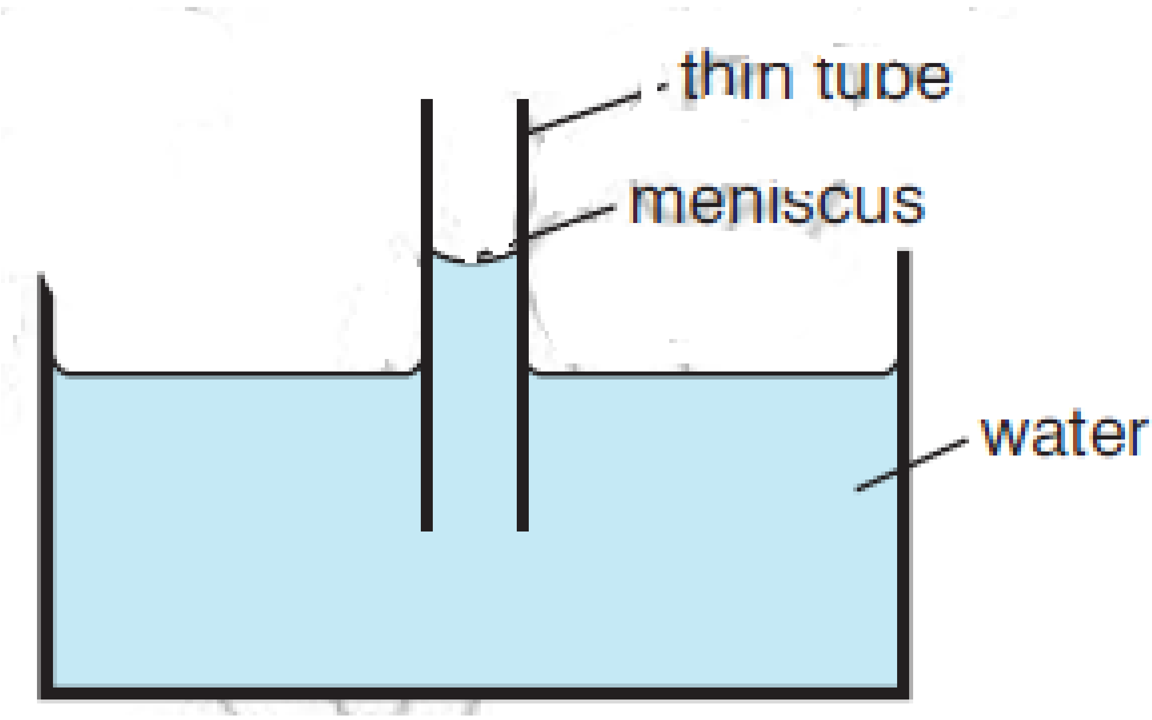


Fig. 24.1. Capillary action

Fluid Dynamics

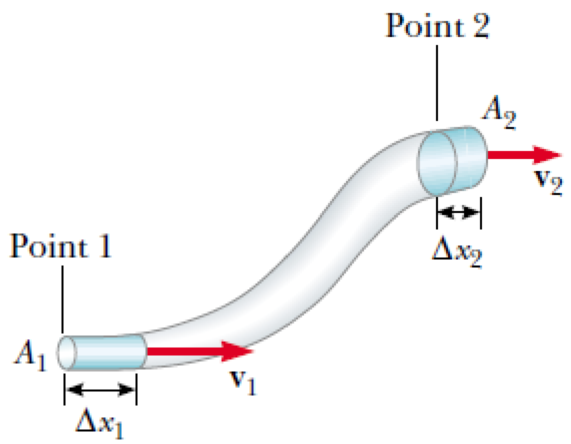
∗ **Stream line/Laminar flow is type of fluid flow where the fluid travels smoothly in regular layer; the velocity and the pressure remain constant at every point in the fluid or the fluid flow in which the adjacent layers of the fluid does not mix with each other and moves parallel to each other.**

∗ **Turbulent flow is type of fluid flow where there disruption to the layer of fluid; the speed of the fluid at any point is continuously changing both in magnitude and direction or the fluid flow in which the adjacent layers of the fluid cross each other and do not move parallel to each other.**

∗ **Equation of Continuity: The equation of continuity expresses conservation of mass in fluid dynamics. It states that " The product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid."**

$$Av = constant \tag{24.17}$$

$$A_1 v_1 = A_2 v_2 \tag{24.18}$$



The product Av, which has the dimensions of volume per unit time, is called volume flow rate or volume flux.

$$Q = AV \tag{24.19}$$

where Q is volume flow rate and its SI unit unit is m^3/s.

$*$ **Volume flow rate of a fluid is volume past a give point per unit time.**

The condition Av = constant is equivalent to the statement that "the volume of fluid that enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval if no leaks are present".

$$Q_1 = Q_2 \tag{24.20}$$

$*$ **The mass flow rate is the mass flow per unit time through a cross section. This is equal to the density ρ times the volume flow rate Q.**

$$R_m = \rho A v \tag{24.21}$$

The SI unit of mass flow rate is kilogram per second (kg/s).

$*$ **Equation of Continuity can also be written as 'The mass flow rate (ρAv) has the same**

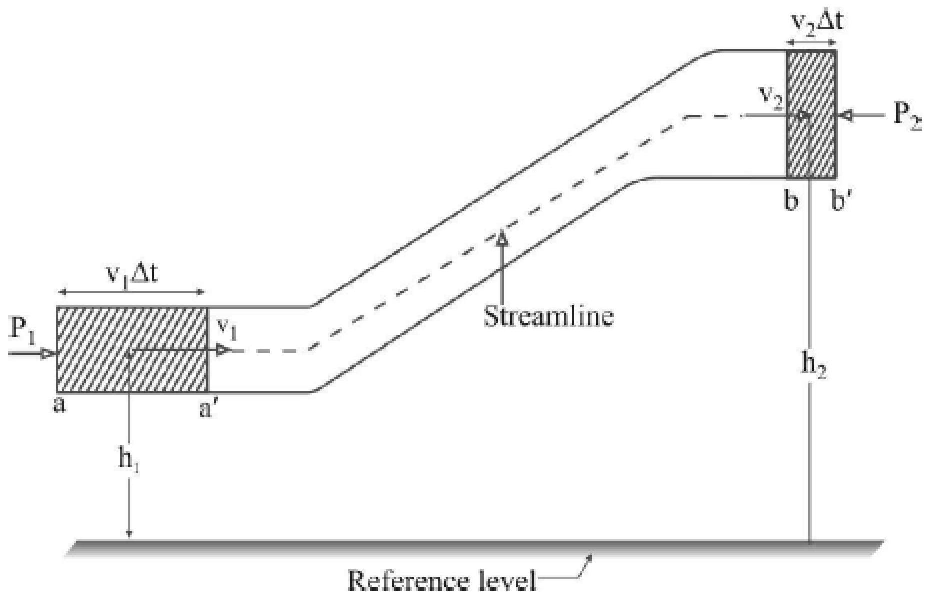
value at every position along a tube that has a single entry and a single exit point for fluid flow.'

$$\rho A_1 v_1 = \rho A_2 v_2 \tag{24.22}$$

$*$ **Common application of equation of continuity are pipe, tubes and ducts with flowing fluids or gases, rivers, over all processes as power plants, roads, computer network and semiconductors technology.**

$*$ **Bernoulli's Equation: Bernoulli's equation states that a quantity involving the pressure p, flow speed v, and elevation h has the same value anywhere in a flow tube, assuming steady flow in an ideal fluid.**

$$p + \rho gh + \frac{1}{2}\rho v^2 = constant \tag{24.23}$$



$$p_1 + \rho gh_1 + \frac{1}{2}\rho v_1^2 = p_2 + \rho gh_2 + \frac{1}{2}\rho v_2^2 \tag{24.24}$$

$*$ **Bernoulli's equation can also be states that the sum of the pressure, kinetic energy per unit volume, and gravitational potential energy per unit volume has the same value at all points along a streamline.** $*$ **The expression p + ρgh + $\frac{1}{2}\rho v^2$ = constant $\rightarrow$ shows that the**

pressure of a fluid decreases as the speed of the fluid increases. In addition, the pressure decreases as the elevation increases.

∗ **Bernoulli's equation can also be written as:**

$$\frac{p}{\rho} + gh + \frac{1}{2}v^2 = constant \qquad (24.25)$$

where $\frac{p}{\rho}$ is represent the pressure - energy (the energy acquired by a fluid by applying pressure on a fluid), gh represent the potential energy per unit mass and $\frac{1}{2}v^2$ represent kinetic energy per unit mass

∗ **In Bernoulli's equation, the term (P + ρgh) is called static pressure, because it is the pressure of the fluid even if it is at rest, and the term $\frac{1}{2}\rho v^2$ is called dynamic pressure of the fluid. Bernoulli's equation thus can be written as:**

Static pressure + dynamic pressure = Constant.

∗ **When a moving fluid is contained in a horizontal pipe, all parts of it have the same elevation (h_1 = h_2), and Bernoulli's equation simplifies to**

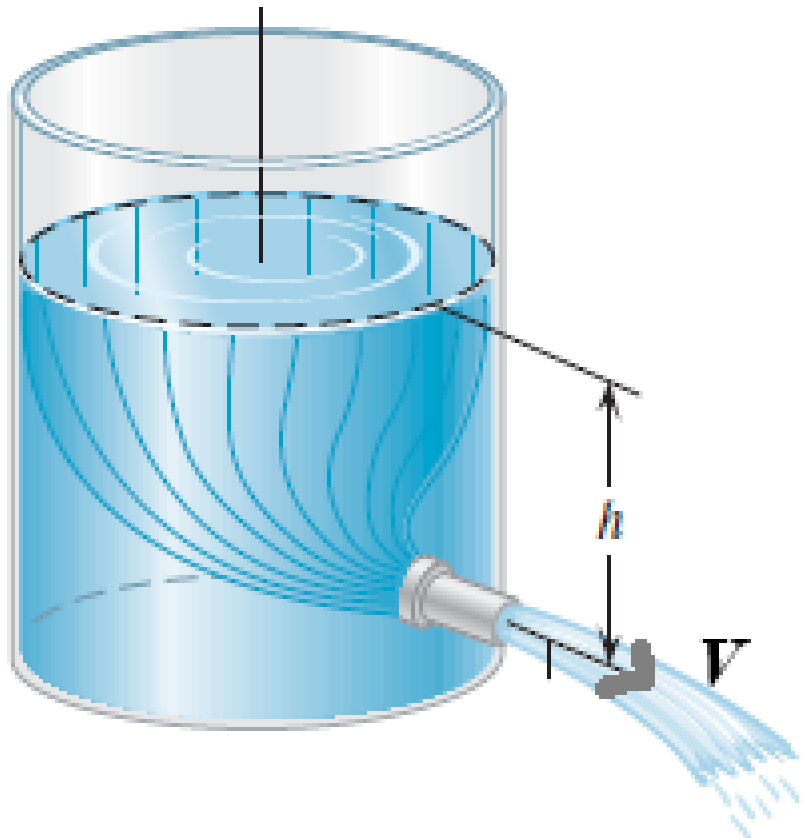
$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2 \qquad (24.26)$$

∗ **which tells us that:**

If the speed of a fluid element increases as the element travels along a horizontal streamline, the pressure of the fluid must decrease, and conversely.

∗ **Torricelli's Theorem: Torricelli's theorem states that 'The speed v of fluid coming out through a hole at the bottom of an open tank filled to a depth h below the surface equals the speed v that a body acquire in falling freely from a height h.'**

$$v = \sqrt{2gh} \qquad (24.27)$$



∗ Viscosity: Viscosity is internal friction in a fluid. Viscous forces oppose the motion of one portion of a fluid relative to another. The force required to drive the layers is given by

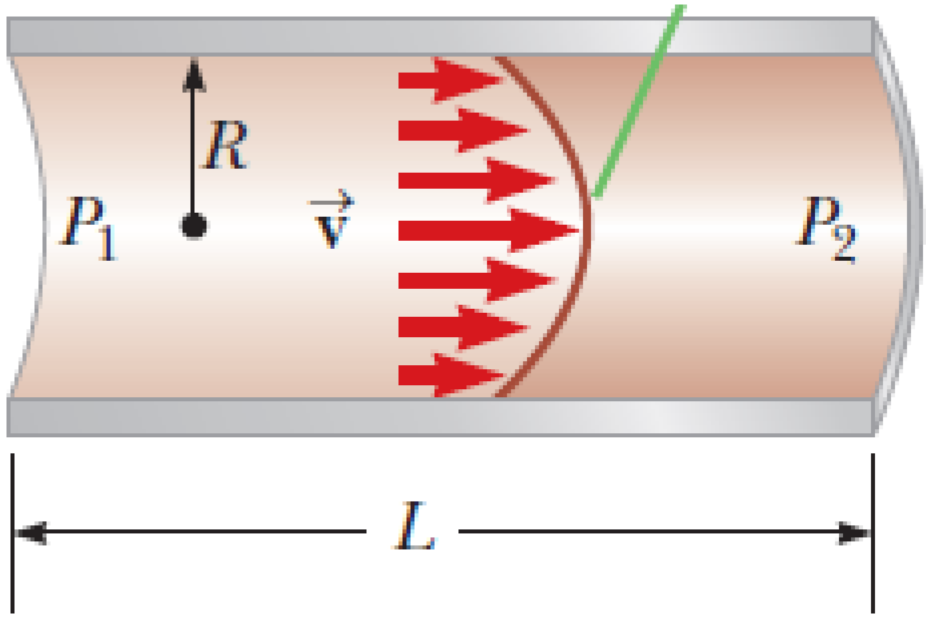
$$F = \eta A \frac{\Delta v}{\Delta y} \qquad (24.28)$$

where η is coefficient of viscosity of liquid or simply viscosity and its SI unit is Pa·s.

∗ Poiseuille's Law: A fluid whose viscosity is η, flowing through a pipe of radius R and length L, has a volume flow rate Q given by

$$Q = \frac{\pi R^4 (P_1 - P_2)}{8\eta L} \qquad (24.29)$$

∗ Stokes's law and terminal velocity: The magnitude of the viscous drag force F that acts on a very small spherical object of radius r falling slowly through a fluid of viscosity



η with speed v is given by

$$F = 6\pi\eta rv \quad (24.30)$$

∗ **Terminal velocity is the maximum constant velocity reached by a falling body when the drag force acting on it is equal to the force of gravity acting on it.**

∗ **Reynolds Number is a dimensionless quantity that is used to determine the type of flow pattern as laminar or turbulent while flowing through a pipe. Reynolds number, RN, given by**

$$RN = \frac{\rho vd}{\eta} \quad (24.31)$$

where r is the density of the fluid, v is the average speed of the fluid along the direction of flow, d is the diameter of the tube, and η is the viscosity of the fluid.

∗ **In the case of fluid flow through a straight pipe with a circular cross - section, Reynolds numbers of less than 2300 are generally considered to be of laminar type. However the Reynolds numbers at which laminar flow becomes turbulent is dependent up on the flow geometry.**

Heat, temperature and thermal

∗ **If a quantity of energy Q is transferred to a substance of mass m, changing its temperature by ΔT =** T_f **-** T_i**, the specific heat capacity c of the substance is defined by**

$$c = \frac{Q}{m\Delta T} \tag{24.32}$$

∗ **Specific heat capacity of a substance is defined as the heat energy required to rise the temperature of 1 kg of a given substance by 1 K.**

∗ **From the definition of specific heat capacity, we can express the energy Q needed to raise the temperature of a system of mass m by ΔT as**

$$Q = mc\Delta T \tag{24.33}$$

∗ **Specific heat is essentially a measure of how thermally insensitive a substance is to the addition of energy. The greater a material's specific heat, the more energy must be added to a given mass of the material to cause a particular temperature change.**

∗ **The heat capacity of a substance (C) is defined as the amount of heat energy required to raise the temperature of a substance by 1 K.**

$$C = \frac{Q}{\Delta T} \tag{24.34}$$

∗ **heat capacity of a substance is the product of the mass and specific heat capacity of a substance.**

$$C = mc \tag{24.35}$$

∗ **Calorimetry: experimental approach to measuring heat capacities and heat changes during chemical and physical processes.**

∗ **The physical characteristics of a substance changes from one form to another, commonly referred to as phase change. Any phase change involves a change in the internal**

energy, but no change in temperature.

∗ **Latent Heat is the amount of energy released or absorbed by a substance during a change of state that occurs without a change in temperature. The energy Q needed to change the phase of a given mass m of pure substance is**

$$Q = \pm mL \tag{24.36}$$

where L, called the specific latent heat of the substance, depends on the nature of the phase change as well as on the substance. The plus sign (heat entering) is used when the material melts; the minus sign (heat leaving) is used when it freezes.

∗ **The specific latent heat of the substance is the amount of energy needed to change the state of 1 kg of the substance without changing its temperature.**

∗ **Specific latent heat of fusion L_f is defined as the quantity of heat required to change 1 kg of a substance from solid to liquid state at its melting point. The heat energy Q_f required to change a substance from a solid to a liquid is**

$$Q_f = mL_f \tag{24.37}$$

∗ **Specific latent heat of vaporization L_v is defined as the quantity of heat required to change 1 kg of a substance from liquid to gaseous state at its boiling point. The heat energy Q_v required to change a substance from a liquid to a gas is**

$$Q_v = mL_v \tag{24.38}$$

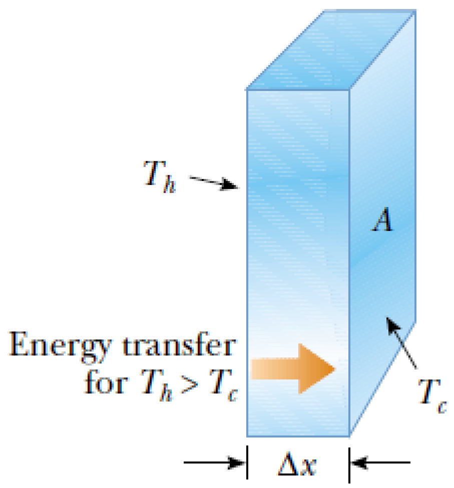
Heat Transfer Mechanisms

∗ **Conduction or thermal conduction is the process by which heat is transferred through a material by collisions of adjacent atoms or molecules. During conduction, energy of**

thermal motion is passed along from one molecule to the next, while each individual molecule remains at its original position.

∗ **In the process of conduction, the thermal energy transfer is viewed as an exchange of average kinetic energy of atoms or molecules from energetic molecules to the less energetic ones.**

∗ **Consider a slab of material of thickness Δx and cross-sectional area A with its opposite faces at different temperatures T_c and T_h, where $T_h > T_c$ as shown in figure. The slab allows energy to transfer from the region of higher temperature to the region of lower temperature by thermal conduction. The rate of energy transfer P = Q /Δt, is proportional to the cross-sectional area of the slab and the temperature difference ΔT = T_h - T_c and is inversely proportional to the thickness of the slab:**



$$p = \frac{Q}{\Delta t} \propto A\frac{\Delta T}{\Delta x} \tag{24.39}$$

$$p = kA\frac{\Delta T}{\Delta x} \tag{24.40}$$

where k, a proportionality constant that depends on the material, is called the thermal conductivity and $\frac{\Delta T}{\Delta x}$ is the temperature gradient (the rate at which temperature.

∗ **thermal conductivity is a measurement of the ability of a material to conduct heat.**

∗ **Substances that are good conductors have large thermal conductivities, whereas good**

insulators have low thermal conductivities.

∗ Convection is the process of heat transfer by the movement of a warm substance.

∗ Radiation is the process of heat transfer by means of EMW.

∗ Stefan - Boltzmann law: 'The rate at which an object radiates energy is proportional to the fourth power of its absolute temperature.'

$$P = eA\sigma T^4 \tag{24.41}$$

where P is the power in watts radiated from the surface of the object, σ is a constant equal to 5.67 x 10^{-8} W/$m^2 \cdot K^4$, A is the surface area of the object in square meters, e is the emissivity, and T is the surface temperature in kelvins. The value of e can vary between zero and unity, depending on the properties of the surface of the object.

∗ Newton's law of cooling: 'The rate of loss of heat from a body is proportional to its excess temperature above its surrounding.'

Topics Related Questions on Unit

Choose the correct answer for the following Questions

1) **Which one of the following statements is FALSE?**

   (A) Strain is a dimensionless measure of the deformation of an object.

   (B) A tensile (stretching) force applied to the ends of a wire exerts a shear stress on the wire.

   (C) An elastic object can return to its original shape, provided the applied force is not too large.

   (D) Tensile strain is the fractional change in length.

   Answer A tensile (stretching) force applied to the ends of a wire exerts a tensile stress on the wire.

   choice B is correct

2) Consider a material that is being stressed within its proportional limit. A wire made of this material has a length L and a cross-sectional area A and is subject to a tensile force F. As a result, the length of the wire changes by ΔL. The wire is now cut in half, and the same tensile force F is applied to one of the halves. What is the change of length of this wire of length $\frac{1}{2}$L when the force F is applied to it?

(A) $\frac{1}{2}$ΔL (B) $\frac{1}{4}$ΔL (C) ΔL (D) 2ΔL

Solution: $L_{o,1}$ **= L,** ΔL_1 **= ΔL,** $L_{o,2}$ **=** $\frac{1}{2}$**L, Y, F and A are the same**

ΔL_2 **= ?**

$\frac{FL_{o,1}}{A\Delta L_1} = \frac{FL_{o,2}}{A\Delta L_2} \Rightarrow \frac{FL}{A\Delta L} = \frac{F\frac{1}{2}L}{A\Delta L_2}$

$\frac{1}{\Delta L} = \frac{1}{2\Delta L_2} \Rightarrow \Delta L_2 = \frac{1}{2}\Delta L$

choice A is correct

3) A fluid has a density of 1040 kg/m^3. If it rises to a height of 1.8 cm in a 1 mm diameter capillary tube, what is the surface tension of the liquid? Assume a contact angle of zero. (g = 10 m/s^2)

(A) 0.056 N/m (B) 0.0468 N/m (C) 0.092 N/m (D) 0.11 N/m

Solution: ρ **= 1040 kg/m^3, h = 1.8 cm = 1.8 x 10^{-2} m, d = 1 mm**

r = 0.5 mm = 5 x 10^{-4} m g = 10 m/s^2 and $\theta = 0^o$

f = ?

h = $\frac{2f\cos\theta}{\rho gr} \Rightarrow$ **f =** $\frac{\rho grh}{2\cos\theta}$

f = $\frac{(1040kg/m^3)(10m/s^2)(5x10^{-4}m)(1.8x10^{-2}m)}{2\cos 0^o}$ **= 0.0468 N**

choice B is correct

4) A hydraulic press has one piston of diameter 2 cm and the other piston of diameter 8 cm. If a 100 N force is applied to the smaller piston, the force exerted on the larger piston will be:

(A) 1600 N (B) 25 N (C) 100 N (D) 400 N

Solution: d_1 **= 2 cm,** F_1 **= 100 N,** d_2 **= 8 cm**

F_2 **= ?**

$\frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow \frac{F_1}{\pi\frac{d_1^2}{4}} = \frac{F_2}{\pi\frac{d_2^2}{4}} \Rightarrow \frac{F_1}{d_1^2} = \frac{F_2}{d_2^2}$

$F_2 = (\frac{d_2}{d_1})^2 F_1 = (\frac{8cm}{2cm})^2$ **x 100 N = 1600 N**

choice A is correct

5) **A block of wood has density 0.50 g/cm^3 and mass 1500 g. It floats in a container of oil (ρ_{oil} = 0.75 g/cm^3). What volume of oil does the wood displace?**

(A) 3000 cm^3 **(B) 2000 cm^3** **(C) 1500 cm^3** **(D) 1000 cm^3**

Solution: ρ_{object} **= 0.50 g/**cm^3**,** m_{object} **= 1500 g,** ρ_{oil} **= 0.75 g/**cm^3

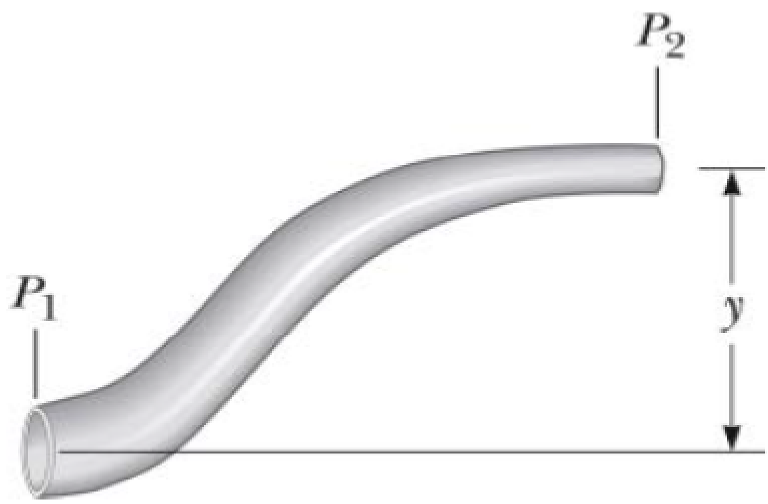
the volume of the fluid displaced by the object(V_{fluid}**) = ?**

$\rho_{object} = \frac{m_{object}}{V_{object}} \Rightarrow V_{object} = \frac{m_{object}}{\rho_{object}} \Rightarrow V_{object} = \frac{1500g}{0.50g/cm^3}$ **= 3000** cm^3

$\frac{V_{fluid}}{V_{object}} = \frac{\rho_{object}}{\rho_{fluid}} \Rightarrow \frac{V_{fluid}}{3000cm^3} = \frac{0.50g/cm^3}{0.75g/cm^3} \Rightarrow V_{fluid} = (\frac{0.50g/cm^3}{0.75g/cm^3})$ **x 3000** cm^3 **= 2000** cm^3

choice B is correct

6) **Water moves through the pipe shown figure below in steady, ideal flow. Which one of the following statements is correct concerning the pressure and flow speed in region 2 compared to region 1?**



(A) Both the pressure and flow speed are higher in region 2 than in region 1.

(B) Both the pressure and flow speed are lower in region 2 than in region 1.

(C) The pressure is lower in region 2 but the flow speed is higher than in region 1.

(D) The pressure is higher in region 2 but the flow speed is lower than in region 1.

Answer From Bernoulli's Equation p + ρgh + $\frac{1}{2}\rho v^2$ = constant $\rightarrow$ shows that the pressure of a fluid decreases as the speed of the fluid increases. In addition, the pressure decreases as the elevation increases.

choice C is correct

7) A lawn sprinkler is made of a 1 cm diameter garden hose with one end closed and 25 holes, each with a diameter of 0.050 cm, cut near the closed end. If water flows at 2 m/s in the hose, what is the speed of the water leaving a hole?

(A) 2 m/s (B) 32 m/s (C) 40 m/s (D) 600 m/s

Solution: d_1 **= 1 cm,** v_1 **= 2 m/s,** d_2 **= 0.050 cm, n = 25**

$v_2 = ?$

$A_1 v_1 = \mathbf{n} A_2 v_2 \Rightarrow \pi \frac{d_1^2}{4} v_1 = 25(\pi \frac{d_2^2}{4} v_2) \Rightarrow d_1^2 v_1 = (25)(d_2^2 v_2)$

$v_2 = (\frac{v_1}{25})(\frac{d_1}{d_2})^2 = (\frac{2m/s}{25})(\frac{1cm}{0.05cm})^2 \Rightarrow v_2 = 32$ **m/s**

choice B is correct

8) A spherical object of radius r falls through a fluid of viscosity η with a speed v. When the object reaches its terminal velocity which one of the following statements is TRUE?

(A) The net force on the object has magnitude mg.

(B) The object has an acceleration of g.

(C) The viscous drag force causes the net force on the object to be zero.

(D) The viscous drag force is in the same direction as the force of gravity on the object.

Answer Terminal velocity is the maximum constant velocity reached by a falling body when the drag force acting on it is equal to the force of gravity acting on it.

$f_r = F_g \Rightarrow F_{net} = 0$.

choice C is correct

9) The rate of heat flow by conduction through a slab does NOT depend upon the:

(A) temperature difference between opposite faces of the slab

(B) thermal conductivity of the slab

(C) slab thickness

(D) specific heat capacity of the slab

Answer The rate of heat flow by conduction through a slab is given by p = kA$\frac{\Delta T}{\Delta x}$. There fore, the rate of heat flow by conduction through a slab does not depend upon the specific heat capacity of the slab

choice D is correct

10) According to the Stefan-Boltzmann law of thermal radiation for a perfect radiator, the rate of radiant energy per unit area is proportional to

(A) the temperature of that radiator

(B) the square of the temperature of that radiator

(C) the cube of the temperature of that radiator

(D) the fourth power of the temperature of that radiator

Answer Stefan-Boltzmann law: 'The rate at which an object radiates energy is proportional to the fourth power of its absolute temperature.'

P = eA$\sigma T^4 \Rightarrow \frac{P}{A}$ **= e**$\sigma T^4 \Rightarrow \frac{P}{A} \propto T^4$

choice D is correct