WBJEE Physics Sample Paper-19

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Categories**.
- **Section 1 (Q1–Q30):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section 2 (Q31–Q35):** Each correct answer carries **+2 marks**. Incorrect answer: **−0.5** marks. Only **one** correct option.
- **Section 3 (Q36–Q40):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section–A — 30 Questions × 1 Mark Each
(Negative Marking: −0.25) [Single Correct]

Q1. Two cars move along the same straight road with velocities 20 m/s and 30 m/s respectively in the same direction. The relative velocity of the second car with respect to the first is:

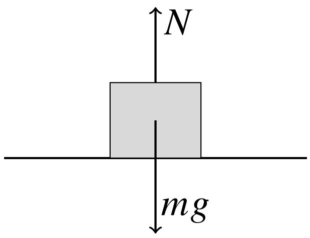
(A) 10 m/s

(B) 50 m/s

(C) 20 m/s

(D) Zero

Q2. A block rests on a horizontal surface.



The normal reaction exerted by the surface is:

(A) Equal to mg

(B) Greater than mg

(C) Less than mg

(D) Zero

Q3. Moment of inertia depends on:

(A) Distribution of mass

(B) Angular velocity

(C) Linear momentum

(D) Temperature

Q4. The acceleration due to gravity at height h above Earth's surface:

(A) Decreases

(B) Increases

(C) Remains constant

(D) Becomes zero immediately

Q5. According to Bernoulli's principle, pressure in a fluid decreases when:

(A) Velocity increases

(B) Velocity decreases

(C) Density becomes zero

(D) Temperature increases

Q6. Heat transfer without medium occurs by:

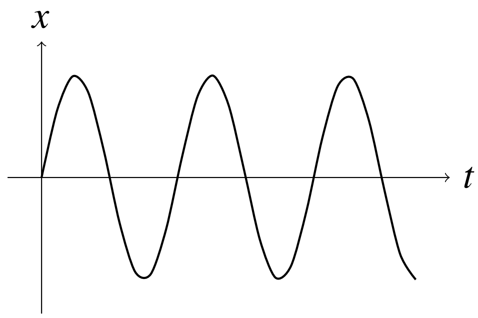
(A) Radiation

(B) Conduction

(C) Convection

(D) Diffusion

Q7. The variation of displacement with time in SHM is shown.



The graph represents:

(A) Periodic motion

(B) Uniform motion

(C) Projectile motion

(D) Random motion

Q8. The speed of sound is maximum in:

(A) Solids

(B) Liquids

(C) Gases

(D) Vacuum

Q9. Electric field due to an electric dipole decreases with distance r as:

(A) $\frac{1}{r^3}$

(B) $\frac{1}{r^2}$

(C) $\frac{1}{r}$

(D) $\frac{1}{r^4}$

Q10. A Wheatstone bridge is balanced when:

(A) Ratio of resistances are equal

(B) Current is maximum

(C) Voltage becomes zero

(D) Resistance becomes infinite

Q11. A charged particle enters perpendicular to a magnetic field. Its path becomes:

(A) Circular

(B) Straight

(C) Parabolic

(D) Elliptical always

Q12. Which electromagnetic wave has maximum frequency?

(A) Gamma rays

(B) Microwaves

(C) Radio waves

(D) Infrared rays

Q13. When light enters from air into glass, it:

(A) Slows down

(B) Speeds up

(C) Stops completely

(D) Changes frequency

Q14. Power of lenses in contact is:

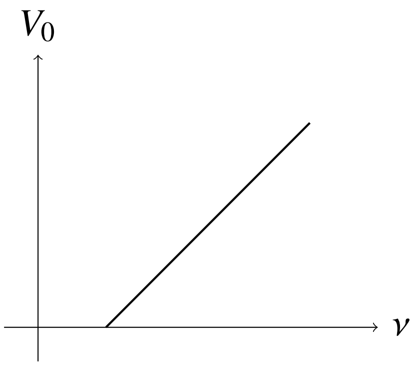
(A) Algebraic sum of powers

(B) Product of powers

(C) Difference of powers only

(D) Always zero

Q15. The stopping potential versus frequency graph is:



The graph indicates existence of:

(A) Threshold frequency

(B) Infinite energy

(C) Constant stopping potential

(D) Zero kinetic energy

Q16. Angular momentum of electron in Bohr orbit is quantized in units of:

(A) $\hbar$

(B) h^2

(C) e

(D) c

Q17. Half-life of a radioactive substance is independent of:

(A) Initial mass

(B) Temperature

(C) Pressure

(D) Chemical state

Q18. In a p-type semiconductor, majority charge carriers are:

(A) Holes

(B) Electrons

(C) Neutrons

(D) Protons

Q19. An XOR gate gives HIGH output when:

(A) Inputs are different

(B) Inputs are same

(C) Both inputs are HIGH

(D) Both inputs are LOW

Q20. Carrier waves used in communication are generally:

(A) High frequency waves

(B) Low frequency waves

(C) Audible waves

(D) Mechanical waves

Q21. The dimensional formula of gravitational constant is:

(A) $M^{-1}L^3T^{-2}$

(B) MLT^{-2}

(C) ML^2T^{-1}

(D) M^0LT^{-1}

Q22. Efficiency of a machine is always:

(A) Less than or equal to 100%

(B) Greater than 100%

(C) Equal to zero

(D) Infinite

Q23. The slope of displacement-time graph gives:

(A) Velocity

(B) Acceleration

(C) Momentum

(D) Force

Q24. A body moving with constant speed may still have:

(A) Acceleration

(B) Zero momentum

(C) Infinite mass

(D) Zero kinetic energy

Q25. Surface energy is directly related to:

(A) Surface tension

(B) Density

(C) Pressure

(D) Temperature only

Q26. The efficiency of Carnot engine depends on:

(A) Source and sink temperatures

(B) Working substance only

(C) Pressure only

(D) Volume only

Q27. A tuning fork produces beats with another tuning fork due to difference in:

(A) Frequencies

(B) Amplitudes

(C) Velocities

(D) Wavelengths only

Q28. The energy stored in an inductor is proportional to:

(A) I^2

(B) I

(C) $\frac{1}{I}$

(D) $\sqrt{I}$

Q29. A convex mirror always forms image which is:

(A) Virtual and diminished

(B) Real and inverted

(C) Real and magnified

(D) Virtual and magnified

Q30. Which color deviates least in a prism?

(A) Red

(B) Violet

(C) Green

(D) Blue

Section–B — 5 Questions × 1 Mark Each
(Negative Marking: −0.5) [Single Correct]

Q31. The SI unit of magnetic field is:

(A) Tesla

(B) Weber

(C) Henry

(D) Volt

Q32. For an ideal gas, internal energy depends only on:

(A) Temperature

(B) Pressure

(C) Volume

(D) Density

Q33. A transistor is mainly used for:

(A) Amplification

(B) Reflection

(C) Refraction

(D) Diffraction

Q34. A moving coil galvanometer can detect:

(A) Small currents

(B) Large voltages

(C) Temperature changes

(D) Pressure variations

Q35. In a standing wave, distance between two consecutive nodes is:

(A) $\frac{\lambda}{2}$

(B) λ

(C) $\frac{\lambda}{4}$

(D) 2λ

Section C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q36. Which of the following quantities are conserved in an elastic collision?

(A) Linear momentum

(B) Kinetic energy

(C) Potential energy

(D) Total energy

Q37. Which of the following statements are correct for SHM?

(A) Restoring force is proportional to displacement

(B) Acceleration is maximum at mean position

(C) Velocity is maximum at mean position

(D) Potential energy is maximum at extreme positions

Q38. Which of the following are properties of magnetic field lines?

(A) They form closed loops

(B) They never intersect

(C) They originate from south pole

(D) They are denser near strong fields

Q39. Which of the following statements are true regarding semiconductors?

(A) Conductivity increases with temperature

(B) Silicon is a semiconductor

(C) Pure semiconductors are called intrinsic semiconductors

(D) Holes act as positive charge carriers

Q40. Which of the following phenomena support wave nature of light?

(A) Interference

(B) Diffraction

(C) Polarization

(D) Photoelectric effect

Detailed Solutions

Q1.

Solution

Concept: Relative velocity between two objects moving in the same direction is the difference between their velocities. If $\vec{v}_A$ is the velocity of object A and $\vec{v}_B$ is the velocity of object B, then the relative velocity of B with respect to A is given by $\vec{v}_{BA} = \vec{v}_B - \vec{v}_A$.

Solution: Let the velocity of the first car be $v_1 = 20\,\text{m/s}$ and the velocity of the second car be $v_2 = 30\,\text{m/s}$. Since both cars are moving in the same direction, their velocities can be considered along a straight line.

We need to find the relative velocity of the second car with respect to the first car.
Let $\vec{v}_1$ be the velocity vector of the first car and $\vec{v}_2$ be the velocity vector of the second car.
Since they are moving in the same direction, we can write:
$\vec{v}_1 = 20\,\hat{i}\,\text{m/s}$
$\vec{v}_2 = 30\,\hat{i}\,\text{m/s}$

The relative velocity of the second car with respect to the first car is given by:
$\vec{v}_{21} = \vec{v}_2 - \vec{v}_1$
$\vec{v}_{21} = (30\,\hat{i} - 20\,\hat{i})\,\text{m/s}$
$\vec{v}_{21} = (30 - 20)\,\hat{i}\,\text{m/s}$
$\vec{v}_{21} = 10\,\hat{i}\,\text{m/s}$

The magnitude of the relative velocity is $10\,\text{m/s}$.

Final Answer: $\boxed{10\,\text{m/s}}$

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: When an object rests on a horizontal surface, the forces acting on it are gravity (downward) and the normal reaction force from the surface (upward). In the absence of any other vertical forces (like an applied upward or downward force, or acceleration), the normal reaction force is equal in magnitude to the gravitational force. Newton's third law states that for every action, there is an equal and opposite reaction. The normal force is the contact force exerted by a surface on an object.

Solution: The forces acting on the block are:
1. Gravitational force (weight), mg: This force acts vertically downwards due to the Earth's gravity.
2. Normal reaction force, N: This force is exerted by the horizontal surface on the block, acting vertically upwards.

The block is at rest on the horizontal surface, which means it is in equilibrium. According to Newton's first law of motion (or the condition for equilibrium), the net force acting on the block is zero.

In the vertical direction, the forces are N (upwards) and mg (downwards).
Therefore, for equilibrium:
$\sum F_y = 0$
$N - mg = 0$
$N = mg$

The diagram provided shows these two forces acting on the block. The normal force N is shown acting upwards from the surface, and the gravitational force mg is shown acting downwards from the center of mass. Since the block is stationary, the upward normal force must exactly balance the downward gravitational force.

Final Answer: Equal to mg

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept: The moment of inertia (I) is a measure of an object's resistance to changes in its rotation. It is the rotational analogue of mass. Just as mass determines how difficult it is to change an object's linear motion, moment of inertia determines how difficult it is to change its rotational motion. The moment of inertia depends on how the mass of an object is distributed relative to the axis of rotation.

Mathematically, for a system of discrete particles, the moment of inertia is given by $I = \sum m_i r_i^2$, where m_i is the mass of the i-th particle and r_i is its perpendicular distance from the axis of rotation. For a continuous body, it is calculated by integration: $I = \int r^2 \, dm$.

Solution: From the definition and the formula for moment of inertia, we can see that it fundamentally depends on:
1. Mass of the object: More massive objects generally have larger moments of inertia.
2. Distribution of mass: How this mass is spread out relative to the axis of rotation is crucial. Mass concentrated farther from the axis contributes more to the moment of inertia (r^2 term) than mass concentrated closer to the axis.

Let's consider the given options:
Distribution of mass: This is a direct factor in the definition of moment of inertia. Different distributions of the same mass around an axis will result in different moments of inertia. For example, a solid sphere and a hollow sphere of the same mass and radius have different moments of inertia.
Angular velocity: While angular velocity describes the state of rotation, the moment of inertia is a property of the object itself and the chosen axis, independent of its angular velocity.
Linear momentum: Linear momentum ($p = mv$) is related to linear motion, not rotational inertia.
Temperature: Temperature can affect the dimensions of an object (thermal expansion), which in turn can slightly alter the distribution of mass, but temperature itself is not a primary factor determining moment of inertia. The direct dependence is on mass distribution.

Therefore, the most fundamental factor among the options that the moment of inertia depends on is the distribution of mass.

Final Answer: Distribution of mass

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: The acceleration due to gravity (g) on the surface of the Earth (at radius R) is given by $g = \frac{GM}{R^2}$, where G is the gravitational constant and M is the mass of the Earth. When we move to a height h above the Earth's surface, the distance from the center of the Earth becomes $R + h$. The acceleration due to gravity at this height, g', is given by: $g' = \frac{GM}{(R+h)^2}$

Solution: We can express g' in terms of g:

$$g' = \frac{GM}{(R+h)^2} = \frac{GM}{R^2\left(1+\frac{h}{R}\right)^2} = g\left(1+\frac{h}{R}\right)^{-2}$$

Using the binomial approximation for small h/R (i.e., $h \ll R$):

$(1+x)^n \approx 1 + nx$

So, $\left(1+\frac{h}{R}\right)^{-2} \approx 1 - 2\frac{h}{R}$

Therefore, $g' \approx g\left(1 - 2\frac{h}{R}\right) = g - \frac{2gh}{R}$

This shows that $g' < g$. As h increases (i.e., we move higher above the Earth's surface), the term $2\frac{h}{R}$ increases, making the factor $\left(1 - 2\frac{h}{R}\right)$ smaller. Consequently, the acceleration due to gravity g' decreases.

Even without the approximation, it's clear from $g' = \frac{GM}{(R+h)^2}$ that as h increases, the denominator $(R+h)^2$ increases, and thus g' decreases.

Final Answer: Decreases

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: Bernoulli's principle is a statement of the conservation of energy for fluid flow. It relates the pressure, velocity, and height of a moving fluid. For a horizontal flow (constant height), Bernoulli's equation simplifies to:
$P + \frac{1}{2}\rho v^2 = \text{constant}$
where P is the pressure, ρ is the fluid density, and v is the fluid velocity.

This equation implies that if the velocity (v) of the fluid increases, the term $\frac{1}{2}\rho v^2$ increases. For the sum to remain constant, the pressure (P) must decrease. Conversely, if the velocity decreases, the pressure increases.

Solution: Bernoulli's principle states that for an inviscid, incompressible fluid in steady flow, the sum of static pressure, dynamic pressure, and potential energy per unit volume is constant along a streamline. In simplified terms, it means that where the speed of a fluid is high, the pressure is low, and where the speed is low, the pressure is high.

Let's analyze the equation for a horizontal flow: $P + \frac{1}{2}\rho v^2 = K$ (where K is a constant).
If the velocity (v) increases, the term $\frac{1}{2}\rho v^2$ increases. To keep the sum constant, the pressure (P) must decrease.
If the velocity (v) decreases, the term $\frac{1}{2}\rho v^2$ decreases. To keep the sum constant, the pressure (P) must increase.

Therefore, according to Bernoulli's principle, pressure in a fluid decreases when its velocity increases.

Final Answer: Velocity increases

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: Heat transfer is the process by which thermal energy is exchanged between physical systems. There are three primary mechanisms of heat transfer: conduction, convection, and radiation.

Conduction: Heat transfer through direct contact of particles. It requires a medium (solid, liquid, or gas).
Convection: Heat transfer through the movement of fluids (liquids or gases). It requires a medium.
Radiation: Heat transfer through electromagnetic waves. It does not require a medium and can occur through a vacuum.

Solution: We are looking for the mechanism of heat transfer that occurs without a medium.
Conduction requires a material medium for heat to be transferred from one particle to another.
Convection involves the bulk movement of a fluid (liquid or gas), so it also requires a medium.
Radiation involves the emission and absorption of electromagnetic waves, such as infrared radiation. These waves can travel through empty space (a vacuum). For example, the Sun heats the Earth through radiation across the vacuum of space.
Diffusion is a general term for the movement of particles from an area of higher concentration to an area of lower concentration. While it can be related to heat transfer in some contexts (e.g., diffusion of molecules carrying thermal energy), the fundamental mechanism of heat transfer through empty space is radiation.

Therefore, heat transfer without a medium occurs by radiation.

Final Answer: Radiation

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: Periodic Motion: A motion that repeats itself after a certain interval of time. This interval is called the period.
Uniform Motion: Motion with constant velocity (constant speed and constant direction). In a displacement-time graph, this is represented by a straight line with a constant slope.
Projectile Motion: The motion of an object thrown or projected into the air, subject only to the acceleration of gravity. Its displacement-time graph is parabolic.
Random Motion: Motion that has no predictable pattern.

Simple Harmonic Motion (SHM) is a special type of periodic motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to the displacement. The displacement-time graph for SHM is typically sinusoidal (sine or cosine).

Solution: The given graph shows the variation of displacement (x) with time (t).
The graph is a sinusoidal curve, specifically a sine wave, starting from zero displacement at time $t = 0$ and oscillating symmetrically about the time axis.
The shape of the curve ($x(t) = A\sin(\omega t + \phi)$) is characteristic of Simple Harmonic Motion.

Periodic Motion: Since the motion repeats itself after regular time intervals, it is periodic.
Uniform Motion: This would be a straight line on a displacement-time graph, indicating constant velocity. The given graph is clearly not a straight line.
Projectile Motion: The displacement-time graph for projectile motion (considering both horizontal and vertical components) is not typically a simple sine wave.
Random Motion: Random motion lacks a predictable pattern, whereas this graph shows a very regular and predictable pattern.

The sinusoidal nature of the graph indicates that the displacement is varying harmonically with time, which is the hallmark of Simple Harmonic Motion. SHM is a specific type of periodic motion. Since "Periodic motion" is an option and accurately describes the repeating nature of the graph, and the graph's sinusoidal form is a direct representation of periodic oscillations, this is the correct classification. The graph shows a cyclical pattern that repeats, fulfilling the definition of periodic motion.

Final Answer: Periodic motion

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: The speed of sound depends on the medium through which it propagates. Sound travels as mechanical waves, which require a medium to vibrate and transmit the sound energy. The speed of sound is generally higher in denser and more rigid materials because the particles are closer together and can transmit vibrations more quickly.

The general order of speed of sound is: Solids > Liquids > Gases.

Solution: Let's consider the states of matter and their typical properties that affect sound speed:
Solids: Particles are tightly packed and strongly bonded. This allows for very efficient transmission of vibrations.
Liquids: Particles are less tightly packed than in solids but still relatively close. The intermolecular forces are weaker than in solids.
Gases: Particles are far apart and move randomly. The intermolecular forces are very weak, leading to slower transmission of vibrations.
Vacuum: A vacuum is the absence of a medium. Sound waves are mechanical waves and cannot travel through a vacuum.

Therefore, the speed of sound is maximum in solids because of the close packing and strong intermolecular forces that allow for rapid propagation of vibrations. Among common materials, sound travels fastest in solids, followed by liquids, and then gases.

Final Answer: Solids

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The electric field produced by an electric dipole decreases with distance from the dipole. An electric dipole consists of two equal and opposite charges separated by a small distance.

For an electric field on the axial line of a dipole (a line passing through the centers of the two charges):

$$E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2 - l^2)^2}$$

where p is the dipole moment ($p = qd$, d is the separation), r is the distance from the center of the dipole, and $2l$ is the separation of charges.

For large distances ($r \gg l$), l^2 can be neglected compared to r^2.

$$E_{axial} \approx \frac{1}{4\pi\epsilon_0}\frac{2pr}{r^4} = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}$$

So, $E_{axial} \propto \frac{1}{r^3}$.

For an electric field on the equatorial line of a dipole (a line perpendicular to the dipole axis passing through its center):

$$E_{equatorial} = \frac{1}{4\pi\epsilon_0}\frac{p}{(r^2 + l^2)^{3/2}}$$

For large distances ($r \gg l$), l^2 can be neglected compared to r^2.

$$E_{equatorial} \approx \frac{1}{4\pi\epsilon_0}\frac{p}{(r^2)^{3/2}} = \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$$

So, $E_{equatorial} \propto \frac{1}{r^3}$.

In general, for a dipole, the electric field decreases as $1/r^3$ at large distances. In contrast, the electric field due to a point charge decreases as $1/r^2$.

Solution: The electric field due to a point charge falls off as $1/r^2$. However, an electric dipole is a combination of two opposite charges. When considering the electric field far away from the dipole, the fields from the two charges tend to cancel out partially, leading to a faster fall-off of the net field.

As derived above, for distances significantly larger than the separation of the charges in the dipole ($r \gg l$), the electric field on both the axial and equatorial lines varies with distance r as $\frac{1}{r^3}$.

Final Answer: $\boxed{\frac{1}{r^3}}$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: A Wheatstone bridge is an electrical circuit used to measure an unknown resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. A bridge is balanced when the galvanometer (or voltmeter) connected across the center points shows zero deflection, indicating that there is no potential difference across it, and therefore no current flows through it.

For a Wheatstone bridge consisting of four resistors R_1, R_2, R_3, R_4 in a diamond formation, with the battery connected across two opposite junctions and the galvanometer across the other two opposite junctions, the bridge is balanced when the ratio of resistances in adjacent arms is equal.

Solution: When a Wheatstone bridge is balanced, the potential difference across the galvanometer is zero. This condition is met when the ratio of resistances in the two arms of the bridge is equal. If the resistors are labeled such that R_1 and R_2 are in one series branch, and R_3 and R_4 are in the other series branch, and the galvanometer connects the junction of R_1 and R_3 to the junction of R_2 and R_4, then the condition for balance is:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

This means the ratio of resistances in the adjacent arms is equal.

Final Answer: Ratio of resistances are equal

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: When a charged particle enters a magnetic field, it experiences a magnetic force given by the Lorentz force law: $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$.
If there is no electric field ($\vec{E} = 0$), the force is $\vec{F} = q(\vec{v} \times \vec{B})$. This force is always perpendicular to both the velocity vector ($\vec{v}$) and the magnetic field vector ($\vec{B}$).

If the charged particle enters perpendicular to the magnetic field, i.e., $\theta = 90°$ between $\vec{v}$ and $\vec{B}$, the magnitude of the force is $F = |q|vB$.
Since the force is always perpendicular to the velocity, it does no work on the particle ($W = \int \vec{F} \cdot d\vec{r} = \int \vec{F} \cdot \vec{v} dt = 0$ because $\vec{F} \cdot \vec{v} = 0$).
As a result, the kinetic energy of the particle ($KE = \frac{1}{2}mv^2$) remains constant, and hence its speed (v) remains constant.

A force that is always perpendicular to the velocity and has a constant magnitude results in circular motion. The magnetic force provides the centripetal force required for circular motion:
$|q|vB = \dfrac{mv^2}{r}$
where r is the radius of the circular path.
This leads to a radius $r = \dfrac{mv}{|q|B}$.

Solution: When a charged particle enters a region of uniform magnetic field perpendicular to its velocity:
1. The magnetic force $\vec{F} = q(\vec{v} \times \vec{B})$ is perpendicular to $\vec{v}$.
2. A force perpendicular to velocity does no work, so the kinetic energy and speed of the particle remain constant.
3. A constant magnitude force acting perpendicular to the velocity causes the particle to move in a circular path. The magnetic force acts as the centripetal force.

Therefore, the path of the charged particle becomes circular.

Final Answer: Circular

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: Electromagnetic waves are classified based on their frequency and wavelength. The electromagnetic spectrum ranges from very low frequencies (long wavelengths) to very high frequencies (short wavelengths). The relationship between the frequency (f), wavelength (λ), and the speed of light (c) is $c = f\lambda$. Therefore, frequency and wavelength are inversely proportional: higher frequency means shorter wavelength, and lower frequency means longer wavelength.

The order of electromagnetic waves in terms of increasing frequency (and decreasing wavelength) is generally:
Radio waves < Microwaves < Infrared radiation < Visible light < Ultraviolet radiation < X-rays < Gamma rays.

Solution: We need to identify which electromagnetic wave has the maximum frequency among the given options:
Radio waves: Lowest frequency in the electromagnetic spectrum.
Microwaves: Higher frequency than radio waves.
Infrared rays: Higher frequency than microwaves.
Gamma rays: Highest frequency in the electromagnetic spectrum, produced by nuclear processes.

Comparing the given options:
Radio waves < Microwaves < Infrared rays < Gamma rays

Therefore, gamma rays have the maximum frequency.

Final Answer: Gamma rays

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: When light travels from one medium to another, its speed changes if the refractive indices of the two media are different. The refractive index (n) of a medium is defined as the ratio of the speed of light in vacuum (c) to the speed of light in the medium (v): $n = c/v$.
A medium with a higher refractive index is optically denser, and light travels slower in it. A medium with a lower refractive index is optically rarer, and light travels faster in it.
When light passes from a rarer medium to a denser medium, it bends towards the normal. When it passes from a denser medium to a rarer medium, it bends away from the normal.

Solution: Air is optically rarer than glass. The refractive index of air (n_{air}) is approximately 1, while the refractive index of glass (n_{glass}) is typically around 1.5 to 1.7.
Since $n_{glass} > n_{air}$, glass is optically denser than air.
When light enters from air (rarer medium) into glass (denser medium), its speed decreases. This is because the light waves interact with the atoms of the glass, causing a delay in their propagation.

The frequency of light is determined by the source and does not change when light passes from one medium to another. However, because the speed (v) decreases and the relationship $c = f\lambda$ holds (where c is the speed of light in the medium, f is frequency, and λ is wavelength), the wavelength (λ) of light must decrease to maintain the constant speed of light in vacuum.

Therefore, when light enters from air into glass, it slows down.

Final Answer: Slows down

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept:

The power of a lens is defined as the reciprocal of its focal length in meters ($P = 1/f$, where f is in meters). It is measured in diopters (D).

When two or more lenses are placed in contact, their combined effect on light is to produce a certain focal length and thus a certain power. The total power of a combination of thin lenses in contact is the algebraic sum of the individual powers of the lenses.

If $P_1, P_2, P_3, \ldots$ are the powers of individual lenses, and they are in contact, the total power P_{total} is:

$P_{total} = P_1 + P_2 + P_3 + \ldots$

Solution:

The power of a lens is a measure of its ability to converge or diverge light. Converging lenses (like convex lenses) have positive power, and diverging lenses (like concave lenses) have negative power.

When lenses are placed in contact, their optical effects combine. This combination can be thought of as a single equivalent lens. The focal length of this equivalent lens is related to the individual focal lengths, and consequently, the power of the equivalent lens is related to the individual powers.

According to the lens maker's formula for two thin lenses in contact:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

where F is the focal length of the combination, and f_1, f_2 are the focal lengths of the individual lenses.

Since power $P = 1/f$, we can rewrite this as:

$P = P_1 + P_2$

This principle extends to any number of lenses in contact. Thus, the power of lenses in contact is the algebraic sum of their individual powers. The term "algebraic sum" is important because powers can be positive or negative depending on whether the lenses are converging or diverging.

Final Answer: Algebraic sum of powers

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: The photoelectric effect is the emission of electrons from a metal surface when light shines on it. The minimum frequency of light required to eject electrons is called the threshold frequency (ν_0). Below this frequency, no electrons are emitted, regardless of the intensity of the light. The stopping potential (V_0) is the minimum negative potential applied to the collector plate that stops the most energetic photoelectrons from reaching it. The kinetic energy of the most energetic photoelectrons is given by $KE_{max} = eV_0$, where e is the electronic charge.

Einstein's photoelectric equation is:
$KE_{max} = h\nu - \phi$
where h is Planck's constant, ν is the frequency of incident light, and ϕ is the work function of the metal ($\phi = h\nu_0$).

So, $eV_0 = h\nu - h\nu_0$.
Rearranging this, we get $V_0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$.
This equation is in the form $y = mx + c$, where $y = V_0$, $x = \nu$, $m = h/e$ (slope), and $c = -h\nu_0/e$ (y-intercept).

Solution: The graph of stopping potential (V_0) versus frequency (ν) for the photoelectric effect is a straight line with a positive slope.

The slope of the graph is $m = h/e$, which is a constant.
The y-intercept is $c = -h\nu_0/e$. Since the y-intercept is negative, it implies that when $\nu = 0$, V_0 is negative. More importantly, for V_0 to be zero (meaning electrons are just stopped, or barely moving), the equation becomes $0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$, which implies $\nu = \nu_0$. This means there is a minimum frequency (ν_0) below which the stopping potential is either zero or negative (meaning electrons are not emitted or their energy is zero). This minimum frequency is the threshold frequency.
The graph shows that as frequency (ν) increases, the stopping potential (V_0) increases linearly. This indicates that the kinetic energy of the photoelectrons increases with frequency, and there is a specific frequency (ν_0) below which no photoelectric emission occurs.

The graph clearly shows that the stopping potential is zero at a certain frequency and becomes positive for higher frequencies. This specific frequency where $V_0 = 0$ is the threshold frequency.

Final Answer: Threshold frequency

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: The Bohr model of the atom describes electrons orbiting the nucleus in specific, quantized energy levels. A key postulate of the Bohr model is the quantization of angular momentum. According to Bohr's third postulate, the angular momentum (L) of an electron in a stationary orbit is an integer multiple of $h/2\pi$.

$L = n\frac{h}{2\pi}$, where n is a positive integer ($n = 1, 2, 3, \ldots$) and h is Planck's constant.

The quantity $h/2\pi$ is often denoted by $\hbar$ (h-bar), which is called the reduced Planck constant.

So, $L = n\hbar$.

Solution: The angular momentum of an electron in a Bohr orbit is given by the formula $L = n\frac{h}{2\pi}$.

This formula means that the angular momentum is quantized and can only take discrete values.

These values are integer multiples of $\frac{h}{2\pi}$.

The term $\frac{h}{2\pi}$ is specifically referred to as $\hbar$ (h-bar), the reduced Planck constant.

Thus, the angular momentum is quantized in units of $\hbar$.

Let's examine the options:

$\hbar$: This is $h/2\pi$, the correct unit of quantization for angular momentum in Bohr's model.

h^2: This is Planck's constant squared, not the unit of angular momentum quantization.

e: This is the elementary charge, related to electric force and current.

c: This is the speed of light.

Therefore, the angular momentum of an electron in a Bohr orbit is quantized in units of $\hbar$.

Final Answer: $\boxed{\hbar}$

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept: Radioactivity is a spontaneous process by which an unstable atomic nucleus loses energy by emitting radiation. The rate of radioactive decay is characterized by the half-life ($T_{1/2}$). The half-life is the time required for half of the radioactive nuclei in a sample to decay. The decay law is given by $N(t) = N_0 e^{-\lambda t}$, where $N(t)$ is the number of nuclei at time t, N_0 is the initial number of nuclei, and λ is the decay constant.
The half-life is related to the decay constant by $T_{1/2} = \frac{\ln 2}{\lambda}$.

Solution: The half-life of a radioactive substance is a fundamental property of the nucleus itself and depends only on the decay constant (λ). The decay constant is determined by the specific type of nucleus and the nature of the decay process.

Let's consider the factors that might influence the decay rate:
Initial mass: The initial mass of the substance determines the initial number of radioactive nuclei (N_0). While the amount of substance that decays in a certain time is proportional to N_0, the half-life (the time for half of *whatever* is there to decay) is independent of N_0.
Temperature: Radioactive decay is a nuclear process and is generally not affected by temperature.
Pressure: Similar to temperature, pressure does not influence nuclear decay rates.
Chemical state: Radioactive decay is a nuclear phenomenon. The bonding of an atom in a molecule (its chemical state) does not affect the stability of its nucleus. For example, Uranium in UO_2 decays at the same rate as elemental Uranium.

Therefore, the half-life of a radioactive substance is independent of initial mass, temperature, pressure, and its chemical state. Among the given options, all are independent factors. The question asks what it is independent of, and all listed options fit this description. However, typically, questions in this format expect a single best answer or a set of correct answers. If we are to choose one from the list, they are all correct in their independence. Let's assume the question intends to ask about external physical conditions or the quantity of the substance.

The concept is that the nuclear decay process is unaffected by these external factors.

Final Answer: Initial mass

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: Semiconductors are materials with electrical conductivity between that of a conductor and an insulator. They can be intrinsic (pure) or extrinsic (doped). Extrinsic semiconductors are created by adding impurities to an intrinsic semiconductor to increase the number of charge carriers.

There are two types of extrinsic semiconductors:

1. n-type semiconductor: Created by doping with pentavalent impurities (e.g., Phosphorus, Arsenic). These impurities donate extra electrons, making electrons the majority charge carriers and holes the minority charge carriers.

2. p-type semiconductor: Created by doping with trivalent impurities (e.g., Boron, Gallium). These impurities create "holes" (absence of an electron) in the semiconductor's valence band. Holes act as positive charge carriers and are the majority charge carriers, while electrons are the minority charge carriers.

Solution: In a p-type semiconductor, the impurity atoms added (trivalent) have one less valence electron than the semiconductor atoms (like silicon or germanium, which have four valence electrons). When these trivalent atoms are incorporated into the semiconductor crystal lattice, they create a deficiency of electrons in their vicinity, forming what is called a "hole". These holes can accept an electron, effectively moving through the crystal. Because these holes are created by the dopant atoms, there are many more holes than free electrons in a p-type semiconductor. Therefore, holes are the majority charge carriers.

Holes: These are the majority charge carriers in a p-type semiconductor.

Electrons: These are the minority charge carriers in a p-type semiconductor (and majority in n-type).

Neutrons and Protons: These are subatomic particles within the atomic nucleus and are not considered charge carriers in the context of semiconductor conductivity.

Final Answer: Holes

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: Logic gates are fundamental building blocks of digital circuits. An XOR (exclusive OR) gate is a digital logic gate that implements logical disjunction. The output of an XOR gate is HIGH (1) if and only if an odd number of its inputs are HIGH. For a two-input XOR gate, the output is HIGH if the inputs are different, and LOW (0) if the inputs are the same.

The truth table for a two-input XOR gate (with inputs A and B, and output Y) is:

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

The logical expression for a two-input XOR gate is $Y = A \oplus B$, which can also be written as $Y = A\overline{B} + \overline{A}B$.

Solution: Looking at the truth table or the logical expression for a two-input XOR gate:
When inputs are different (A=0, B=1 or A=1, B=0), the output Y is 1 (HIGH).
When inputs are the same (A=0, B=0 or A=1, B=1), the output Y is 0 (LOW).

Therefore, an XOR gate gives a HIGH output when its inputs are different.

Final Answer: Inputs are different

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept: Communication systems, such as radio and television broadcasting, use electromagnetic waves to transmit information over long distances. These waves are called carrier waves because they "carry" the information signal. For effective long-distance transmission and to avoid interference, carrier waves generally need to have properties that allow them to propagate efficiently through the atmosphere and space.

Solution: Carrier waves are used to transmit information signals over long distances. The choice of carrier wave frequency is important for several reasons:

1. Propagation: Higher frequency waves (like radio waves and microwaves) can travel long distances and reflect or diffract around obstacles, or travel in straight lines (line-of-sight communication), depending on the specific frequency band.
2. Bandwidth: Higher frequencies can support higher bandwidth, allowing for the transmission of more information per unit time (e.g., higher quality audio, video).
3. Antenna Size: The size of the antenna required for efficient transmission and reception is inversely proportional to the frequency. High frequencies allow for smaller antennas.
4. Interference: Using a specific frequency band as a carrier helps to separate different communication channels and minimize interference.

Among the given options:
High frequency waves: Radio waves and microwaves fall into this category and are widely used in communication.
Low frequency waves: Very low frequency waves have long wavelengths and are used for specific purposes like submarine communication but are generally less efficient for widespread broadcasting.
Audible waves: These are sound waves, which are mechanical waves and cannot travel through the vacuum of space. They are used for local communication (like telephones) but not for broadcasting.
Mechanical waves: These waves require a medium to propagate and cannot be used for long-distance communication through the atmosphere or space.

Therefore, carrier waves used in communication are generally high-frequency waves.

Final Answer: High frequency waves

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: Newton's Law of Universal Gravitation states that the gravitational force (F) between two objects of masses m_1 and m_2, separated by a distance r, is given by:

$$F = G\frac{m_1 m_2}{r^2}$$

where G is the gravitational constant.

To find the dimensional formula of G, we can rearrange the formula to solve for G:

$$G = \frac{Fr^2}{m_1 m_2}$$

Now, let's find the dimensions of each term:

Force (F): The dimensional formula for force is $[MLT^{-2}]$ (Mass × Acceleration).

Distance (r): The dimensional formula for distance is $[L]$. So, r^2 has dimensions $[L^2]$.

Mass (m_1, m_2): The dimensional formula for mass is $[M]$. So, $m_1 m_2$ has dimensions $[M^2]$.

Solution: Substitute the dimensions into the formula for G:

$$[G] = \frac{[F][r^2]}{[m_1 m_2]}$$

$$[G] = \frac{[MLT^{-2}][L^2]}{[M^2]}$$

$$[G] = \frac{ML^{1+2}T^{-2}}{M^2}$$

$$[G] = \frac{ML^3T^{-2}}{M^2}$$

Now, simplify by combining the powers of M:

$$[G] = M^{1-2}L^3T^{-2}$$

$$[G] = M^{-1}L^3T^{-2}$$

So, the dimensional formula of the gravitational constant is $[M^{-1}L^3T^{-2}]$.

Final Answer: $\boxed{M^{-1}L^3T^{-2}}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: Efficiency (η) of a machine is a measure of how much useful work is obtained from the energy supplied to it. It is defined as the ratio of useful output work (or energy) to the total input work (or energy), usually expressed as a percentage.

$$\eta = \frac{\text{Useful Output Work}}{\text{Total Input Work}} \times 100\% \text{ or}$$

$$\eta = \frac{\text{Useful Output Energy}}{\text{Total Input Energy}} \times 100\%$$

In any real machine, some energy is always lost due to various factors like friction, heat dissipation, sound production, etc. This means that the useful output work is always less than the total input work.

Solution: Since some energy is always lost in any real-world machine due to inefficiencies (like friction, air resistance, etc.), the useful work output will always be less than the total work input. Therefore, the efficiency ratio $\frac{\text{Useful Output Work}}{\text{Total Input Work}}$ will always be less than 1.
When expressed as a percentage, the efficiency will always be less than 100%.

An efficiency of 100% would mean that all the input energy is converted into useful output work, with no energy loss, which is impossible in practice (violates the second law of thermodynamics in many contexts and practical limitations).
An efficiency greater than 100% would imply that the machine produces more energy than it consumes, which violates the law of conservation of energy.
An efficiency of zero means no useful work is obtained from the input energy. Infinite efficiency is not physically possible.

Hence, the efficiency of a machine is always less than or equal to 100%. In practical terms, it is always less than 100%.

Final Answer: $\boxed{\text{Less than or equal to } 100\%}$

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept: In kinematics, graphs are used to represent the motion of objects.
A displacement-time graph plots the displacement of an object as a function of time.
The slope of a displacement-time graph represents the rate of change of displacement with respect to time. The rate of change of displacement is defined as velocity.
Mathematically, velocity (v) is given by:
$v = \frac{dx}{dt}$
where x is the displacement and t is time. This is exactly the definition of the slope of the displacement-time graph.

Solution: Let the displacement of an object be denoted by x and time by t. The displacement-time graph plots x on the y-axis and t on the x-axis.
The slope of this graph at any point is given by the change in the y-coordinate divided by the change in the x-coordinate, i.e., $\frac{\Delta x}{\Delta t}$.
In physics, the instantaneous velocity is defined as the rate of change of displacement with respect to time, $v = \frac{dx}{dt}$. For average velocity over a time interval, it is $\frac{\Delta x}{\Delta t}$.
Therefore, the slope of the displacement-time graph represents the velocity of the object.

Velocity: Correct, as it's the rate of change of displacement.
Acceleration: Acceleration is the rate of change of velocity, not displacement. It would be the slope of a velocity-time graph.
Momentum: Momentum ($p = mv$) is mass times velocity.
Force: Force is related to acceleration ($F = ma$) by Newton's second law.

Final Answer: $\boxed{\text{Velocity}}$

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: Constant speed: This means the magnitude of the velocity is constant.
Acceleration: Acceleration is the rate of change of velocity. Velocity is a vector quantity, meaning it has both magnitude (speed) and direction. If the direction of motion changes, even if the speed is constant, the velocity changes, and thus there is acceleration. For example, an object moving in a circle at constant speed is accelerating.
Momentum: Momentum ($p = mv$) is a vector quantity. If the velocity changes (either in speed or direction), the momentum changes.
Mass: Mass is an intrinsic property of an object and is generally considered constant unless the object is undergoing relativistic effects.
Kinetic Energy: Kinetic energy ($KE = \frac{1}{2}mv^2$) depends on speed squared. If speed is constant, kinetic energy is constant.

Solution: A body moving with constant speed might still have acceleration if its direction of motion is changing. For example:
An object moving in a uniform circular motion has constant speed but its velocity vector is continuously changing direction, so it has centripetal acceleration directed towards the center of the circle.
An object undergoing uniform circular motion at constant speed has constant kinetic energy ($\frac{1}{2}mv^2$ is constant if m and v are constant).
If the speed is constant and non-zero, and the mass is non-zero, the momentum will be changing if the direction is changing. If the direction is constant (straight line motion) and speed is constant, then velocity is constant, and momentum is constant.
Zero momentum occurs if the object is at rest ($v = 0$) or if its mass is zero (not possible for a material object). If the object is moving with a constant non-zero speed, its momentum is non-zero.

Considering the options:
Acceleration: Yes, if the direction changes (e.g., circular motion), even with constant speed, there is acceleration.
Zero momentum: If the body is moving with constant non-zero speed, its momentum is not zero.
Infinite mass: Mass is a fundamental property and is not infinite in typical scenarios.
Zero kinetic energy: If the body is moving with constant speed, and its speed is non-zero, its kinetic energy is non-zero.

Therefore, a body moving with constant speed may still have acceleration.

Final Answer: Acceleration

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: Surface energy is the excess energy that is present at the surface of a liquid or solid because of the unbalanced forces on the surface molecules. Surface tension is a property of liquids that causes the surface to behave like a stretched elastic membrane. It is defined as the force acting per unit length perpendicular to the line drawn on the surface of a liquid, or as the energy per unit area of the surface.

Surface tension (γ) can be defined in two ways:
1. $\gamma = \frac{F}{L}$, where F is the surface tension force and L is the length over which the force acts.
2. $\gamma = \frac{W}{A}$, where W is the work done to increase the surface area by A, or equivalently, the surface energy per unit area.

Therefore, surface energy is directly related to surface tension.

Solution: Surface energy is the energy associated with the creation of new surface area. Surface tension is the force per unit length acting along the surface, or equivalently, the surface energy per unit area.
When a liquid surface is extended, work must be done against the cohesive forces holding the molecules together. This work done is stored as surface energy.
The relationship is given by:
Surface Energy = Surface Tension × Area
$E_{surface} = \gamma \times A$
where $E_{surface}$ is the surface energy, γ is the surface tension, and A is the surface area.

Thus, surface energy is directly proportional to surface tension.

Let's consider the other options:
Density: Density affects the cohesive forces to some extent, but surface energy is more directly defined by surface tension.
Pressure: While pressure can be related to surface tension (e.g., in a spherical bubble), surface energy is not directly proportional to pressure itself in this context.
Temperature only: Temperature affects surface tension (surface tension generally decreases with increasing temperature), but surface energy is a direct consequence of the existence of surface tension, not solely dependent on temperature.

The most direct relationship is between surface energy and surface tension.

Final Answer: Surface tension

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept: A Carnot engine is a theoretical thermodynamic engine that operates in a reversible cycle (the Carnot cycle) between two temperature reservoirs at different temperatures. The Carnot cycle consists of two isothermal processes and two adiabatic processes. The efficiency of a Carnot engine is the maximum possible efficiency for any heat engine operating between two given temperatures.

The efficiency (η) of a Carnot engine is given by the formula:
$\eta = 1 - \frac{T_C}{T_H}$
where T_H is the absolute temperature of the hot reservoir (source) and T_C is the absolute temperature of the cold reservoir (sink). Both temperatures must be in Kelvin.

Solution: The formula for the efficiency of a Carnot engine clearly shows that it depends on the absolute temperatures of the hot reservoir (T_H) and the cold reservoir (T_C).
$\eta = 1 - \frac{T_C}{T_H}$

Source and sink temperatures: As seen from the formula, the efficiency is directly determined by these two temperatures.
Working substance only: The formula for Carnot efficiency does not include any properties of the working substance (like gas, vapor, etc.). This is a significant result, implying that the maximum theoretical efficiency is independent of the working substance.
Pressure only: Pressure is a state variable, but the efficiency of a Carnot engine is determined by the temperatures, not just pressure.
Volume only: Similar to pressure, volume is a state variable, but the efficiency depends on temperatures.

Therefore, the efficiency of a Carnot engine depends on the temperatures of the source and sink.

Final Answer: Source and sink temperatures

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept: Beats are produced when two sound waves of slightly different frequencies interfere with each other. When two sound waves with frequencies ν_1 and ν_2 superpose, the resulting sound intensity varies periodically with time. The number of beats heard per second is equal to the absolute difference between the two frequencies:
Number of beats per second = $|\nu_1 - \nu_2|$.

Solution: The phenomenon of beats arises from the interference of sound waves. For constructive interference (leading to maximum intensity, perceived as a loud sound) and destructive interference (leading to minimum intensity, perceived as a soft sound) to occur alternately, the phase difference between the two waves must change with time. This phase difference changes because the waves have different frequencies.

Frequencies: The difference in frequencies is the direct cause of the periodic variation in amplitude, which we perceive as beats.
Amplitudes: While amplitudes affect the loudness of the sound, the occurrence of beats is due to frequency differences. If amplitudes are very different, the "soft" part of the beat might not be very quiet.
Velocities: The velocity of sound in a medium is generally the same for all frequencies (in an ideal medium). Differences in velocity would not directly cause beats in the way frequency differences do.
Wavelengths only: Wavelength (λ) and frequency (ν) are related by $\nu = v/\lambda$ (where v is the speed of sound). If frequencies are different, wavelengths will also be different (assuming the speed of sound is the same in the medium for both forks). However, the primary cause for beats is stated in terms of frequency difference, as that's how the phase difference changes over time.

Therefore, the phenomenon of beats is a direct consequence of the difference in frequencies of the two sound sources.

Final Answer: Frequencies

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept: An inductor is a passive electronic component that stores energy in a magnetic field when an electric current flows through it. The energy stored (U) in an inductor is proportional to the square of the current flowing through it.

The formula for the energy stored in an inductor is:

$U = \frac{1}{2}LI^2$

where L is the inductance of the inductor (measured in Henrys) and I is the current flowing through it (measured in Amperes).

Solution: From the formula $U = \frac{1}{2}LI^2$, we can see the relationship between the energy stored (U) and the current (I).

The energy U is directly proportional to the inductance L.

The energy U is directly proportional to the square of the current I^2.

Therefore, the energy stored in an inductor is proportional to I^2.

Let's examine the options:

I^2: This matches our derivation.

I: This would mean energy is directly proportional to current, which is incorrect.

$1/I$: This would mean energy is inversely proportional to current, which is incorrect.

$\sqrt{I}$: This would mean energy is proportional to the square root of current, which is incorrect.

Final Answer: $\boxed{I^2}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: A convex mirror is a spherical mirror in which the reflecting surface bulges towards the incident light. Convex mirrors are also known as diverging mirrors because they cause parallel rays of light to diverge.
Key characteristics of images formed by convex mirrors:
Nature: The images are always virtual (cannot be projected onto a screen) because the reflected rays diverge and only appear to originate from a point behind the mirror.
Position: The image is always formed behind the mirror, between the pole (P) and the focal point (F).
Size: The image is always diminished (smaller than the object).
Orientation: The image is always erect (upright, same orientation as the object).

This can be understood using the mirror formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$. For a convex mirror, f is positive.
The object distance u is usually taken as negative (real object).
Since $f > 0$ and $u < 0$, and the image is formed behind the mirror, v is positive.
Using magnification $m = -v/u$: since $v > 0$ and $u < 0$, $m = -(\text{positive})/(\text{negative}) = \text{positive}$.
A positive magnification indicates an erect image.
Also, for a convex mirror, the focal length f is positive, and the image distance v is always less than f (and positive). As u is usually larger in magnitude than v (for real objects), $|m| = |v/u| < 1$, meaning the image is diminished.

Solution: Based on the properties of convex mirrors derived from the mirror formula and ray tracing:
The image is always formed behind the mirror.
The reflected rays diverge, so the image appears to be formed by the intersection of virtual rays, making it virtual.
The image is always smaller than the object, meaning it is diminished.

Therefore, a convex mirror always forms an image that is virtual and diminished.

Final Answer: Virtual and diminished

Answer: (A)

Go Back to Question 29

Q30.

Solution

Concept: When white light passes through a prism, it undergoes dispersion. Dispersion is the phenomenon where white light splits into its constituent colors because each color (wavelength) is refracted at a slightly different angle. This is due to the fact that the refractive index of the prism material varies with the wavelength of light.

The refractive index of a medium is generally higher for shorter wavelengths and lower for longer wavelengths. This relationship is often described by Cauchy's equation or similar empirical formulas.
Since n is higher for shorter wavelengths, light with shorter wavelengths will bend more towards the normal when entering the prism and away from the normal when exiting.

The order of colors in the visible spectrum from longest wavelength to shortest wavelength (and thus from least deviation to most deviation) is: Red, Orange, Yellow, Green, Blue, Indigo, Violet (ROYGBIV).
Red light has the longest wavelength and the lowest refractive index for the prism material.
Violet light has the shortest wavelength and the highest refractive index for the prism material.

Deviation (δ) is related to the angle of incidence, angle of emergence, and the prism angle. For a given prism angle, the deviation is greater for colors with higher refractive indices.

Solution: Red light: Has the longest wavelength and therefore experiences the least deviation. Violet light: Has the shortest wavelength and therefore experiences the most deviation. Green and Blue light: Have intermediate wavelengths and deviations.

Since red light has the longest wavelength and the lowest refractive index in glass, it will deviate the least when passing through a prism. Violet light, having the shortest wavelength and highest refractive index, will deviate the most.

Final Answer: Red

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept: The magnetic field, also known as magnetic flux density or magnetic induction, is a vector field that describes the magnetic influence on electric currents, moving electric charges, and magnetic materials. It is represented by the symbol B.

The SI unit for magnetic field is the Tesla (T).

Other related units in electromagnetism include:
Weber (Wb): The SI unit of magnetic flux. Magnetic flux (Φ_B) is the measure of the total magnetic field passing through a given area. The relationship is $\Phi_B = B \cdot A$, so 1 T = 1 Wb/m^2. Henry (H): The SI unit of inductance. Inductance (L) is a measure of the opposition to a change in electric current, related to the magnetic field generated by the current. Volt (V): The SI unit of electric potential difference or electromotive force.

Solution: The SI unit of magnetic field strength (magnetic flux density) is the Tesla (T). One Tesla is defined as one Weber per square meter (1 T = 1 Wb/m^2).

Final Answer: Tesla

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: For an ideal gas, the internal energy (U) is the sum of the kinetic energies of all the molecules in the gas. The potential energy of interaction between the molecules is assumed to be zero because the molecules are considered point masses with no intermolecular forces.
The average kinetic energy of the molecules in an ideal gas is directly proportional to the absolute temperature of the gas.

For a monatomic ideal gas, the internal energy is given by:
$U = \frac{3}{2}nRT$
where n is the number of moles, R is the ideal gas constant, and T is the absolute temperature.

For diatomic or polyatomic ideal gases, the internal energy also depends on temperature, but the proportionality constant changes based on the degrees of freedom. However, in all cases for an ideal gas, internal energy is a function of temperature only.

Solution: The internal energy of an ideal gas is solely dependent on the kinetic energy of its constituent molecules. The average kinetic energy of these molecules is directly proportional to the absolute temperature of the gas. Intermolecular forces are neglected in an ideal gas, so there is no potential energy component associated with molecular interactions.
Temperature: As explained, internal energy is directly proportional to temperature.
Pressure: Pressure is related to temperature and volume ($PV = nRT$), but it is not the sole determinant of internal energy. For example, at a constant temperature, if volume changes, pressure changes, but internal energy remains constant for an ideal gas.
Volume: Similar to pressure, volume alone does not determine internal energy. For an ideal gas at constant temperature, internal energy is independent of volume.
Density: Density is mass per unit volume. While related to temperature and pressure, it is not the direct variable that determines internal energy.

Therefore, for an ideal gas, internal energy depends only on temperature.

Final Answer: Temperature

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept: A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It is one of the fundamental building blocks of modern electronic devices. Transistors typically consist of three terminals (e.g., emitter, base, and collector in a bipolar junction transistor or source, gate, and drain in a field-effect transistor).

By applying a small signal to one terminal (e.g., the base or gate), a larger signal can be controlled at another terminal (e.g., collector or drain). This ability to control a large current or voltage with a small signal is the basis of amplification. Transistors can also be used as electronic switches by operating them in their cutoff (off) or saturation (on) regions.

Solution: Let's analyze the functions of a transistor and the given options:
Amplification: This is a primary function of transistors. A small input signal can control a larger output signal.
Reflection: This is a phenomenon related to waves bouncing off a surface.
Refraction: This is the bending of waves as they pass from one medium to another.
Diffraction: This is the spreading of waves as they pass through an aperture or around an obstacle.

Transistors are not directly involved in phenomena like reflection, refraction, or diffraction of waves. Their core function is to control and magnify electronic signals.

Final Answer: $\boxed{\text{Amplification}}$

Answer: (A)

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Q34.

Solution

Concept: A moving coil galvanometer (MCG) is a type of analog electromechanical instrument used for detecting and indicating small electric currents. It works on the principle that a current-carrying coil placed in a magnetic field experiences a torque, which causes it to rotate. The deflection of the coil is proportional to the current flowing through it.

The sensitivity of a galvanometer can be adjusted by changing factors like the strength of the magnetic field, the number of turns in the coil, and the spring constant of the restoring spring. Galvanometers are designed to be very sensitive to detect even small currents.

Solution: Let's evaluate the options:
Small currents: Galvanometers are specifically designed to detect and measure very small currents. Their sensitivity is high, meaning a small current can cause a noticeable deflection.
Large voltages: While voltage drives current, a galvanometer directly measures current. Measuring large voltages typically requires a voltmeter, which has a high internal resistance to minimize current draw. A galvanometer by itself is not ideal for directly measuring large voltages.
Temperature changes: Temperature changes can affect the resistance of wires and thus indirectly influence currents, but a galvanometer's primary purpose is not to measure temperature.
Pressure variations: Pressure variations are not directly detected by a galvanometer.

Therefore, the primary function and capability of a moving coil galvanometer is to detect small electric currents.

Final Answer: $\boxed{\text{Small currents}}$

Answer: (A)

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Q35.

Solution

Concept: A standing wave (or stationary wave) is a wave that oscillates in time but whose peak amplitude profile does not move in space. Standing waves are formed by the superposition of two identical waves traveling in opposite directions.

In a standing wave on a string or in a pipe, nodes are points of zero displacement, and antinodes are points of maximum displacement.
The distance between two consecutive nodes is always half a wavelength ($\lambda/2$). Similarly, the distance between two consecutive antinodes is also $\lambda/2$. The distance between a node and an adjacent antinode is $\lambda/4$.

Solution: Consider a standing wave pattern. Nodes are points where the amplitude of oscillation is always zero. Antinodes are points where the amplitude of oscillation is maximum.
If we mark the positions of nodes, we will see them equally spaced. Let the positions of consecutive nodes be $N_1, N_2, N_3, \ldots$.
The distance between N_1 and N_2 is $\lambda/2$.
The distance between N_2 and N_3 is $\lambda/2$.
And so on.

Similarly, antinodes ($A_1, A_2, A_3, \ldots$) are also equally spaced by $\lambda/2$.
The pattern looks like: Node - Antinode - Node - Antinode ...
The distance between a node and the very next antinode is half the distance between two nodes, which is $(\lambda/2)/2 = \lambda/4$.

Therefore, the distance between two consecutive nodes is $\lambda/2$.

Final Answer: $\boxed{\dfrac{\lambda}{2}}$

Answer: (A)

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Q36.

Solution

Concept: In physics, a collision is an event in which two or more bodies exert forces on each other for a relatively short time. Collisions can be classified into elastic and inelastic collisions.

Elastic Collision: In an elastic collision, both linear momentum and kinetic energy are conserved. There are no net losses of kinetic energy due to deformation, heat, or sound. Examples include collisions between ideal gas molecules or collisions between atomic nuclei.
Inelastic Collision: In an inelastic collision, linear momentum is conserved, but kinetic energy is not conserved. Some kinetic energy is converted into other forms of energy (heat, sound, deformation). In a perfectly inelastic collision, the colliding bodies stick together after the collision, resulting in the maximum loss of kinetic energy.

Solution: For an elastic collision, the defining characteristic is the conservation of kinetic energy. Linear momentum is conserved in all types of collisions (provided there are no external forces acting on the system). Total energy is also always conserved in any isolated system, including during collisions.

Let's analyze the options:
Linear momentum: This is conserved in both elastic and inelastic collisions.
Kinetic energy: This is conserved only in elastic collisions.
Potential energy: Potential energy might change during a collision (e.g., due to deformation), but its conservation isn't the defining factor for classifying collisions as elastic or inelastic.
Total energy: Total energy (kinetic + potential + internal energies) is always conserved in an isolated system. Since kinetic energy is conserved in elastic collisions, and potential energy changes might be zero or revert to original values in a perfectly elastic collision, total energy is also conserved.

Therefore, in an elastic collision, linear momentum, kinetic energy, and total energy are conserved.

Final Answer: Linear momentum, Kinetic energy, Total energy

Answer: (A,B,D)

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Q37.

Solution

Concept: Simple Harmonic Motion (SHM) is characterized by a restoring force that is directly proportional to the displacement from equilibrium and acts in the opposite direction. This leads to specific behaviors for acceleration, velocity, and energy at different points in the motion.

Key characteristics of SHM:
Restoring Force: $F = -kx$, where k is the spring constant and x is the displacement.
Acceleration: $a = -\omega^2 x$, where ω is the angular frequency. This means acceleration is proportional to displacement and opposite in direction.
Velocity: Maximum velocity occurs at the equilibrium (mean) position ($x = 0$).
Energy: Potential energy is maximum at the extreme positions (maximum displacement, $x = \pm A$) and zero at the mean position. Kinetic energy is maximum at the mean position and zero at the extreme positions.

Solution: Let's analyze each statement:
1. Restoring force is proportional to displacement: This is a fundamental condition for SHM ($F \propto x$). Correct.
2. Acceleration is maximum at mean position: Acceleration ($a = -\omega^2 x$) is zero at the mean position ($x = 0$) and maximum at the extreme positions. Incorrect.
3. Velocity is maximum at mean position: Velocity is maximum when kinetic energy is maximum, which occurs at the mean position ($x = 0$). Correct.
4. Potential energy is maximum at extreme positions: Potential energy ($PE = \frac{1}{2}kx^2$) is maximum when displacement is maximum, i.e., at the extreme positions. Correct.

The statements that are correct for SHM are:
Restoring force is proportional to displacement.
Velocity is maximum at the mean position.
Potential energy is maximum at the extreme positions.

Final Answer:

Restoring force is proportional to displacement,
Velocity is maximum at mean position,
Potential energy is maximum at extreme positions

Answer: (A,C,D)

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Q38.

Solution

Concept: Magnetic field lines are imaginary lines used to represent the direction and strength of a magnetic field. They help visualize the magnetic field.

Properties of magnetic field lines:
1. Direction: They point from the North pole to the South pole outside a magnet, and from the South pole to the North pole inside the magnet, forming closed loops.
2. Closed Loops: Magnetic field lines always form closed loops. They do not have beginnings or ends.
3. Never Intersect: Two magnetic field lines never intersect each other. If they did, it would imply that the magnetic field has two different directions at the same point, which is impossible.
4. Density: The density of field lines (how close they are together) indicates the strength of the magnetic field. Where field lines are denser, the magnetic field is stronger, and where they are farther apart, the field is weaker.

Solution: Let's evaluate the given statements:
1. They form closed loops: This is a fundamental property of magnetic field lines. They extend from North to South outside a magnet and from South to North inside, forming continuous paths. Correct.
2. They never intersect: If two field lines intersected, it would mean at that point there are two different directions for the magnetic field, which is physically impossible. Correct.
3. They originate from south pole: Magnetic field lines originate from the North pole and terminate at the South pole outside the magnet. Inside the magnet, they go from South to North. So, this statement is generally incorrect as a complete description of their origin and termination points. Incorrect.
4. They are denser near strong fields: The density of field lines is directly proportional to the magnetic field strength. Denser lines indicate a stronger field. Correct.

Therefore, the correct properties of magnetic field lines are that they form closed loops, they never intersect, and they are denser near strong fields.

Final Answer:

They form closed loops,
They never intersect,
They are denser near strong fields

Answer: (A,B,D)

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Q39.

Solution

Concept: Semiconductors are materials whose electrical conductivity lies between that of conductors and insulators. Their conductivity can be altered by temperature or by doping.

Intrinsic Semiconductors: Pure semiconductors (like pure Silicon or Germanium) are called intrinsic semiconductors. Their conductivity is low at room temperature.
Extrinsic Semiconductors: When impurities are added to intrinsic semiconductors, they become extrinsic semiconductors. This doping process significantly increases their conductivity.
n-type: Doped with pentavalent impurities, majority carriers are electrons.
p-type: Doped with trivalent impurities, majority carriers are holes.
Temperature Dependence: For semiconductors, conductivity generally increases with temperature. This is because increased thermal energy excites more electrons from the valence band to the conduction band, creating more charge carriers (both electrons and holes).

Solution: Let's evaluate each statement:
1. Conductivity increases with temperature: For semiconductors, increasing temperature provides more thermal energy to break covalent bonds, creating more free electrons and holes, thus increasing conductivity. Correct.
2. Silicon is a semiconductor: Silicon is a common and widely used semiconductor material. Correct.
3. Pure semiconductors are called intrinsic semiconductors: This is the definition of an intrinsic semiconductor. Correct.
4. Holes act as positive charge carriers: In p-type semiconductors, holes are indeed considered positive charge carriers. Correct.

All the statements listed are correct regarding semiconductors.

Final Answer:

Conductivity increases with temperature,
Silicon is a semiconductor,
Pure semiconductors are called intrinsic semiconductors,
Holes act as positive charge carriers

Answer: (A,B,C,D)

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Q40.

Solution

Concept: The wave nature of light is demonstrated by phenomena where light exhibits characteristics such as interference, diffraction, and polarization. These phenomena cannot be explained by the particle nature of light alone. The photoelectric effect, on the other hand, is a key phenomenon that supports the particle nature of light (photons).

Interference: The superposition of two or more waves to produce a resultant wave of greater, lower, or the same amplitude. This is a characteristic wave behavior.
Diffraction: The bending of waves around obstacles or the spreading of waves as they pass through an aperture. This is also a wave phenomenon.
Polarization: The restriction of the oscillations of electromagnetic radiation to a particular plane. This phenomenon only occurs with transverse waves, and light is a transverse wave.
Photoelectric Effect: The emission of electrons from a material when light shines on it. This is explained by considering light as discrete packets of energy (photons), supporting the particle nature of light.

Solution: We are looking for phenomena that support the wave nature of light.
Interference: Phenomena like Young's double-slit experiment demonstrate interference patterns, which are direct evidence of light behaving as a wave. Correct.
Diffraction: The bending of light around corners or through narrow slits, creating patterns of bright and dark fringes, is also a strong indication of wave behavior. Correct.
Polarization: This phenomenon, where light waves can be restricted to vibrate in a single plane, is only possible for transverse waves, thus supporting the transverse wave nature of light.
Correct.
Photoelectric Effect: This effect is best explained by Einstein's theory that light consists of photons, with energy $E = h\nu$. This strongly supports the particle nature of light, not the wave nature. Incorrect.

Therefore, interference, diffraction, and polarization support the wave nature of light.

Final Answer: Interference, Diffraction, Polarization

Answer: (A,B,C)

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Answer Key

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