# WBJEE Physics Sample Paper-7

**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 identical conducting spheres carrying charges $+6\,\mu C$ and $-2\,\mu C$ are brought into contact and then separated. The electrostatic force between them at separation $r$ is:

(A) Zero
(B) $\frac{4k}{r^2}$
(C) $\frac{8k}{r^2}$
(D) $\frac{16k}{r^2}$

**Q2.** A wire of resistance $R$ is stretched uniformly so that its length becomes three times its original value. The new resistance becomes:

(A) $3R$

(B) $6R$

(C) $9R$

(D) $27R$

**Q3.** The displacement of a particle executing SHM is given by $x = 4\sin(2t + \pi/3)$ cm. The maximum velocity of the particle is:

(A) 4 cm/s

(B) 8 cm/s

(C) 16 cm/s

(D) 32 cm/s

**Q4.** A solid cylinder and a ring roll down the same incline without slipping. Which has greater acceleration?

(A) Ring

(B) Cylinder

(C) Both equal

(D) Depends on mass

**Q5.** The escape velocity from a planet is 11.2 km/s. If the radius of the planet becomes double and mass remains same, the new escape velocity becomes:

(A) 5.6 km/s

(B) 7.9 km/s

(C) 11.2 km/s

(D) 15.8 km/s

**Q6.** One mole of an ideal gas expands isothermally at temperature $T$. The work done is equal to:

(A) $nRT$

(B) $nRT \ln\left(\frac{V_2}{V_1}\right)$

(C) $\frac{3}{2}RT$

(D) Zero

**Q7.** Water flows through a pipe of varying cross-section. If the radius becomes half, the speed of water becomes:

(A) Half

(B) Double

(C) Four times

(D) Eight times

**Q8.** The equation of a wave is $y = 5\sin(100t - 0.4x)$ SI units. The wavelength is:

(A) $\pi$ m

(B) $5\pi$ m

(C) $10\pi$ m

(D) $20\pi$ m

**Q9.** An open organ pipe resonates at fundamental frequency 200 Hz. The length of the pipe is ($v = 340\,m/s$):

(A) 0.425 m

(B) 0.85 m

(C) 1.7 m

(D) 3.4 m

**Q10.** An object is placed at twice the focal length of a convex lens. The image formed is:

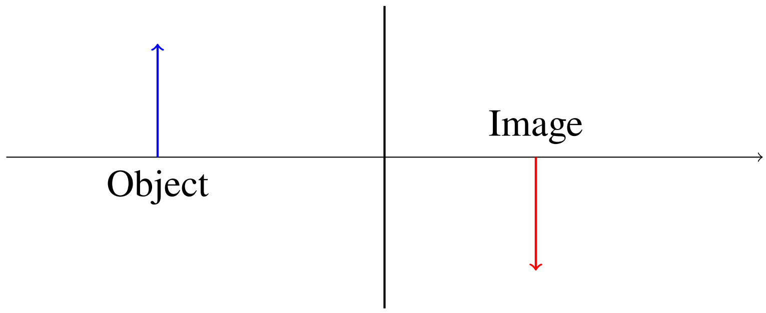
(A) Virtual and erect

(B) Real and same size

(C) Real and magnified

(D) Virtual and diminished

**Q11.** The following figure shows a convex lens forming an image of an object. The nature of the image is:




(A) Virtual and erect

(B) Real and inverted

(C) Virtual and diminished

(D) Real and erect

**Q12.** In Young's double slit experiment, if the distance between slits is doubled, fringe width becomes:

(A) Double

(B) Half

(C) Four times

(D) Unchanged

**Q13.** A charged particle enters a uniform magnetic field parallel to the field lines. The path followed is:

(A) Circular

(B) Helical

(C) Straight line

(D) Parabolic

**Q14.** The magnetic field at the centre of a circular coil carrying current $I$ and radius $R$ is proportional to:

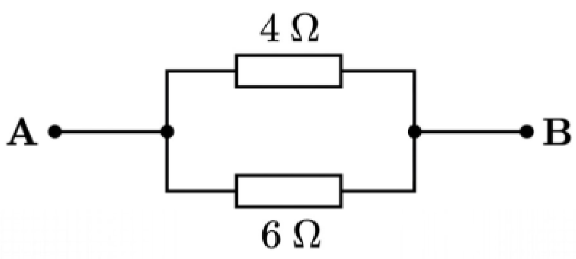
(A) $\frac{I}{R}$

(B) $\frac{R}{I}$

(C) $IR$

(D) $\frac{1}{IR}$

**Q15.** In the following circuit, the equivalent resistance between A and B is:




(A) 2.4Ω

(B) 4Ω

(C) 10Ω

(D) 24Ω

**Q16.** The rms value of an alternating current is 5 A. The peak current is:

(A) $5\sqrt{2}$ A

(B) $\frac{5}{\sqrt{2}}$ A

(C) 10 A

(D) 2.5 A

**Q17.** A p-type semiconductor is formed by doping silicon with:

(A) Phosphorus

(B) Arsenic

(C) Boron

(D) Germanium

**Q18.** The stopping potential in photoelectric effect depends on:

(A) Intensity only

(B) Frequency only

(C) Work function only

(D) Distance from source

**Q19.** The binding energy per nucleon is maximum for:

(A) Hydrogen

(B) Helium

(C) Iron

(D) Uranium

**Q20.** The Boolean expression for NAND gate is:

(A) $A + B$

(B) $\overline{AB}$

(C) $\overline{A + B}$

(D) $AB$

**Q21.** The maximum range of a projectile occurs at an angle of projection:

(A) $30^\circ$

(B) $45^\circ$

(C) $60^\circ$

(D) $90^\circ$

**Q22.** The kinetic energy of a body becomes four times its initial value. Its momentum becomes:

(A) Double

(B) Four times

(C) Eight times

(D) Same

**Q23.** Stress is defined as:

(A) Force × Area

(B) Force / Area

(C) Area / Force

(D) Force × Length

**Q24.** Two capacitors of capacitances 3 $\mu F$ and 6 $\mu F$ are connected in series. The equivalent capacitance is:

(A) 2 $\mu F$

(B) 3 $\mu F$

(C) 4 $\mu F$

(D) 9 $\mu F$

**Q25.** The focal length of a concave mirror is 20 cm. An object is placed at 40 cm from the mirror. The image distance is:

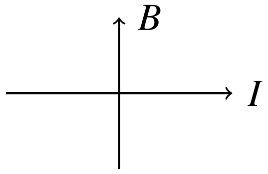
(A) 10 cm

(B) 20 cm

(C) 40 cm

(D) 80 cm

**Q26.** A current carrying conductor is placed perpendicular to a magnetic field as shown. The direction of force is:




(A) Into the plane

(B) Out of the plane

(C) Upward

(D) Downward

**Q27.** The energy of a photon is proportional to:

(A) Wavelength

(B) Frequency

(C) Square of frequency

(D) Velocity

**Q28.** The total energy of a particle executing SHM is proportional to:

(A) Amplitude

(B) Square of amplitude

(C) Frequency

(D) Time period

**Q29.** For an adiabatic process of an ideal gas:

(A) $\Delta Q = 0$

(B) $\Delta U = 0$

(C) $\Delta T = 0$

(D) $W = 0$

**Q30.** The apparent frequency of a sound increases when:

(A) Source moves away

(B) Observer moves away

(C) Source approaches observer

(D) Both move away

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

**Q31.** Electric field lines never intersect because:

(A) Field is scalar

(B) Two tangents cannot exist at one point

(C) Charges are discrete

(D) Potential is constant

**Q32.** In reverse bias, the depletion layer of a p-n junction diode:

(A) Decreases

(B) Remains same

(C) Increases

(D) Vanishes

**Q33.** The number of undecayed nuclei after two half-lives is:

(A) $\frac{N_0}{2}$

(B) $\frac{N_0}{4}$

(C) $\frac{N_0}{8}$

(D) $\frac{N_0}{16}$

**Q34.** A car moves on a circular road of radius $r$. The centripetal acceleration is proportional to:

(A) $v$

(B) $v^2$

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

(D) $\sqrt{v}$

**Q35.** Diffraction effects become prominent when slit width is:

(A) Very large

(B) Equal to wavelength

(C) Infinite

(D) Zero

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

**Q36.** Which of the following phenomena can demonstrate wave nature of light?

(A) Interference

(B) Diffraction

(C) Polarisation

(D) Photoelectric effect

**Q37.** In a series LCR circuit at resonance, which of the following statements are correct?

(A) Impedance is minimum

(B) Current is maximum

(C) Power factor is unity

(D) Inductive reactance equals capacitive reactance

**Q38.** Which of the following statements regarding photoelectric effect are correct?

(A) Emission of electrons is instantaneous

(B) Kinetic energy of emitted electrons depends on frequency

(C) Number of emitted electrons depends on intensity

(D) Threshold frequency depends on intensity

**Q39.** Which of the following statements are correct regarding a p-n junction diode?

(A) It allows current easily in forward bias

(B) Depletion layer decreases in forward bias

(C) Reverse current is usually small

(D) It behaves as an insulator in forward bias

**Q40.** A charged particle enters a uniform magnetic field perpendicular to its velocity. Which of the following statements are correct?

(A) Magnetic force acts on the particle

(B) Speed of the particle remains constant

(C) Path of the particle is circular

(D) Work done by magnetic force is non-zero

# Detailed Solutions

## Q1.

### Solution

**Concept:** When two conducting spheres are brought into contact, charge is redistributed between them until they reach the same electric potential. For identical spheres, the total charge is equally shared. The electrostatic force between two point charges $q_1$ and $q_2$ separated by a distance $r$ is given by Coulomb's Law: $F = k\frac{|q_1 q_2|}{r^2}$, where $k$ is Coulomb's constant.

**Solution:** Step 1: Determine the initial charges on the spheres. Sphere 1: $q_1 = +6\,\mu C$ Sphere 2: $q_2 = -2\,\mu C$

Step 2: Calculate the total charge when the spheres are brought into contact. Total charge $Q_{total} = q_1 + q_2 = (+6\,\mu C) + (-2\,\mu C) = +4\,\mu C$.

Step 3: Since the spheres are identical and conducting, the charge will be equally distributed between them when they are in contact and then separated. Charge on each sphere after separation: $q' = \frac{Q_{total}}{2} = \frac{+4\,\mu C}{2} = +2\,\mu C$.

Step 4: Calculate the electrostatic force between the spheres at separation $r$ after they have been separated. Both spheres now carry a charge of $q' = +2\,\mu C$. The force $F = k\frac{|q' \cdot q'|}{r^2} = k\frac{|(+2\,\mu C)\cdot(+2\,\mu C)|}{r^2} = k\frac{(2\times 10^{-6}\,C)\times(2\times 10^{-6}\,C)}{r^2}$. $F = k\frac{4\times 10^{-12}\,C^2}{r^2}$.

Step 5: Compare the calculated force with the given options. The options are given in terms of $k/r^2$. From our calculation, the force is $4k\frac{(1\,\mu C)^2}{r^2} = \frac{4k}{r^2}\times(1\,\mu C)^2$. However, the options are simplified. Let's re-examine the proportionality. The magnitude of the charge on each sphere is $2\,\mu C$. So, $F = k\frac{(2\,\mu C)(2\,\mu C)}{r^2} = k\frac{4\,(\mu C)^2}{r^2}$. If we express the force in terms of the charge unit $\mu C$, then the charge on each sphere is 2. The force is $F = k\frac{2\times 2}{r^2} = \frac{4k}{r^2}$.

The question asks for the electrostatic force between them at separation $r$. The options are in the form of $constant \times k/r^2$. The charge on each sphere is $2\,\mu C$. So the force is $F = k\frac{(2\,\mu C)(2\,\mu C)}{r^2} = k\frac{4\,(\mu C)^2}{r^2}$. The options do not explicitly contain $\mu C^2$. It's implied that the constant multiplying $k/r^2$ represents the product of charges in a consistent unit system where the unit of charge is implied to be $\mu C$. Therefore, the magnitude of the force is $k\frac{2\times 2}{r^2} = \frac{4k}{r^2}$.

**Final Answer:** $\boxed{\frac{4k}{r^2}}$

**Answer: (B)**

Go Back to Question 1

# Q2.

## Solution

**Concept:** The resistance of a wire is directly proportional to its length and inversely proportional to its cross-sectional area, given by $R = \rho\frac{L}{A}$, where $\rho$ is the resistivity, $L$ is the length, and $A$ is the cross-sectional area. When a wire is stretched uniformly, its volume remains constant. If the length increases by a factor of $n$, the cross-sectional area decreases by a factor of $n^2$ to maintain the same volume.

**Solution:** Step 1: Identify the initial resistance and the relationship between resistance, length, and area.
Let the original length of the wire be $L_1$ and the original cross-sectional area be $A_1$.
The original resistance is $R_1 = R = \rho\frac{L_1}{A_1}$.

Step 2: Determine the new length and the effect on the cross-sectional area.
The wire is stretched uniformly so that its length becomes three times its original value.
New length $L_2 = 3L_1$.
Since the volume of the wire remains constant, $V = L_1A_1 = L_2A_2$.
So, $L_1A_1 = (3L_1)A_2$.
This implies $A_2 = \frac{A_1}{3}$.

Step 3: Calculate the new resistance using the new length and area.
The new resistance $R_2 = \rho\frac{L_2}{A_2}$.
Substitute the expressions for $L_2$ and $A_2$:
$R_2 = \rho\frac{3L_1}{A_1/3} = \rho\frac{3 \times 3L_1}{A_1} = 9\left(\rho\frac{L_1}{A_1}\right)$.

Step 4: Relate the new resistance to the original resistance.
Since $R = \rho\frac{L_1}{A_1}$, we have $R_2 = 9R$.

**Final Answer:** $\boxed{9R}$

**Answer: (C)**

Go Back to Question 2

# Q3.

## Solution

**Concept:** The displacement of a particle executing Simple Harmonic Motion (SHM) is given by an equation of the form $x(t) = A\sin(\omega t + \phi)$ or $x(t) = A\cos(\omega t + \phi)$. Here, $A$ is the amplitude (maximum displacement), $\omega$ is the angular frequency, and $\phi$ is the phase constant. The velocity of the particle is the time derivative of its displacement: $v(t) = \frac{dx}{dt}$. The maximum velocity occurs when $\cos(\omega t + \phi) = \pm 1$, and its magnitude is $v_{max} = A\omega$.

**Solution:** Step 1: Identify the given displacement equation and its parameters.
The displacement of the particle is given by $x = 4\sin(2t + \pi/3)$ cm.
Comparing this with the general form $x(t) = A\sin(\omega t + \phi)$:
Amplitude $A = 4$ cm.
Angular frequency $\omega = 2$ rad/s.
Phase constant $\phi = \pi/3$.

Step 2: Find the velocity of the particle by differentiating the displacement with respect to time.
$v(t) = \frac{dx}{dt} = \frac{d}{dt}[4\sin(2t + \pi/3)]$
Using the chain rule, $\frac{d}{dt}\sin(u) = \cos(u)\frac{du}{dt}$. Here, $u = 2t + \pi/3$, so $\frac{du}{dt} = 2$.
$v(t) = 4\cos(2t + \pi/3) \cdot 2$
$v(t) = 8\cos(2t + \pi/3)$ cm/s.

Step 3: Determine the maximum velocity.
The maximum value of $\cos(\theta)$ is 1. Therefore, the maximum velocity occurs when $\cos(2t + \pi/3) = 1$.
$v_{max} = 8 \times 1$ cm/s.
$v_{max} = 8$ cm/s.

**Final Answer:** $\boxed{8 \text{ cm/s}}$

**Answer: (B)**

Go Back to Question 3

## Q4.

### Solution

**Concept:** When an object rolls down an inclined plane without slipping, its acceleration depends on the distribution of its mass, specifically its moment of inertia ($I$). The linear acceleration ($a$) of the center of mass is given by $a = \frac{g \sin\theta}{1 + I/(MR^2)}$, where $g$ is the acceleration due to gravity, $\theta$ is the angle of inclination, $M$ is the mass, and $R$ is the radius of the object. A smaller value of the ratio $I/(MR^2)$ leads to a greater acceleration.

**Solution:** Step 1: Recall the formula for acceleration of a rolling object down an incline.
The linear acceleration of an object rolling down an inclined plane without slipping is given by:
$a = \frac{g \sin\theta}{1 + \frac{I}{MR^2}}$
where $I$ is the moment of inertia, $M$ is the mass, and $R$ is the radius of the object.

Step 2: Determine the moment of inertia for a solid cylinder and a ring.
For a solid cylinder, $I_{cylinder} = \frac{1}{2}MR^2$.
For a ring (or hollow cylinder), $I_{ring} = MR^2$.

Step 3: Calculate the ratio $I/(MR^2)$ for each object.
For the solid cylinder: $\frac{I_{cylinder}}{MR^2} = \frac{\frac{1}{2}MR^2}{MR^2} = \frac{1}{2}$.
For the ring: $\frac{I_{ring}}{MR^2} = \frac{MR^2}{MR^2} = 1$.

Step 4: Substitute these ratios into the acceleration formula.
Acceleration of the solid cylinder: $a_{cylinder} = \frac{g \sin\theta}{1 + 1/2} = \frac{g \sin\theta}{3/2} = \frac{2}{3} g \sin\theta$.
Acceleration of the ring: $a_{ring} = \frac{g \sin\theta}{1 + 1} = \frac{g \sin\theta}{2}$.

Step 5: Compare the accelerations.
Since $\frac{2}{3} > \frac{1}{2}$, the acceleration of the solid cylinder is greater than the acceleration of the ring.

**Final Answer:** $\boxed{Cylinder}$

**Answer: (B)**

Go Back to Question 4

# Q5.

## Solution

**Concept:** The escape velocity ($v_e$) from the surface of a celestial body is the minimum speed an object needs to escape its gravitational pull without any further propulsion. It is given by the formula $v_e = \sqrt{\frac{2GM}{R}}$, where $G$ is the gravitational constant, $M$ is the mass of the celestial body, and $R$ is its radius.

**Solution:** Step 1: Write the formula for escape velocity.
The escape velocity from a planet is given by:
$$v_e = \sqrt{\frac{2GM}{R}}$$

Step 2: Analyze the given information and the changes.
The initial escape velocity is $v_{e1} = 11.2$ km/s.
Let the initial mass be $M_1$ and the initial radius be $R_1$.
So, $11.2 \text{ km/s} = \sqrt{\frac{2GM_1}{R_1}}$.

The radius of the planet becomes double, so the new radius $R_2 = 2R_1$.
The mass remains the same, so the new mass $M_2 = M_1$.

Step 3: Calculate the new escape velocity.
The new escape velocity $v_{e2} = \sqrt{\frac{2GM_2}{R_2}}$.
Substitute $M_2 = M_1$ and $R_2 = 2R_1$:
$$v_{e2} = \sqrt{\frac{2GM_1}{2R_1}} = \sqrt{\frac{1}{2} \cdot \frac{2GM_1}{R_1}}.$$

Step 4: Relate the new escape velocity to the original escape velocity.
We can rewrite the expression for $v_{e2}$ as:
$$v_{e2} = \sqrt{\frac{1}{2}} \cdot \sqrt{\frac{2GM_1}{R_1}}.$$
Since $v_{e1} = \sqrt{\frac{2GM_1}{R_1}}$, we have:
$$v_{e2} = \frac{1}{\sqrt{2}} v_{e1}.$$

Step 5: Calculate the numerical value of the new escape velocity.
$$v_{e2} = \frac{1}{\sqrt{2}} \times 11.2 \text{ km/s} \approx 0.707 \times 11.2 \text{ km/s}.$$
$v_{e2} \approx 7.9184$ km/s.
This is approximately 7.9 km/s.

**Final Answer:** 7.9 km/s

**Answer: (B)**

**Go Back to Question 5**

# Q6.

## Solution

**Concept:** For an isothermal process, the temperature of the gas remains constant. According to the ideal gas law, $PV = nRT$. If $T$ is constant, then $PV =$ constant. The work done by an ideal gas during an isothermal expansion from an initial volume $V_1$ to a final volume $V_2$ is given by $W = nRT \ln\left(\frac{V_2}{V_1}\right)$.

**Solution:** Step 1: Identify the process and the relevant thermodynamic law.
The process described is an isothermal expansion of an ideal gas.
For an ideal gas, the relationship between pressure ($P$), volume ($V$), number of moles ($n$), and temperature ($T$) is given by the ideal gas law: $PV = nRT$.

Step 2: Understand the condition for an isothermal process.
In an isothermal process, the temperature $T$ remains constant. Therefore, from the ideal gas law, the product $PV$ is also constant: $PV =$ constant.

Step 3: Recall the formula for work done during an isothermal process.
The work done ($W$) by an ideal gas during an isothermal expansion from an initial state $(P_1, V_1)$ to a final state $(P_2, V_2)$ at a constant temperature $T$ is given by:
$W = \int_{V_1}^{V_2} P\,dV$
Since $PV = nRT$, we have $P = \frac{nRT}{V}$.
Substituting this into the integral:
$W = \int_{V_1}^{V_2} \frac{nRT}{V}\,dV$
Since $n$, $R$, and $T$ are constants for an isothermal process:
$W = nRT \int_{V_1}^{V_2} \frac{1}{V}\,dV$
$W = nRT[\ln V]_{V_1}^{V_2}$
$W = nRT(\ln V_2 - \ln V_1)$
$W = nRT \ln\left(\frac{V_2}{V_1}\right)$

Step 4: Consider the given options.
The question states that one mole of an ideal gas expands isothermally at temperature $T$. So, $n = 1$.
The work done is equal to $1 \cdot RT \ln\left(\frac{V_2}{V_1}\right) = RT \ln\left(\frac{V_2}{V_1}\right)$.
Comparing this with the options, option B matches this formula, with $n$ written explicitly.

**Final Answer:** $\boxed{nRT \ln\left(\frac{V_2}{V_1}\right)}$

**Answer: (B)**

Go Back to Question 6

## Q7.

### Solution

**Concept:** The equation of continuity for incompressible fluids states that the volume flow rate ($Q$) is constant throughout a pipe. $Q = Av$, where $A$ is the cross-sectional area and $v$ is the fluid velocity. If the radius of the pipe decreases, the cross-sectional area decreases, and to maintain a constant flow rate, the velocity must increase.

**Solution:** Step 1: State the equation of continuity.
$A_1 v_1 = A_2 v_2$

Step 2: Relate area to radius.
The area of a circular pipe is $A = \pi r^2$.
So, $(\pi r_1^2)v_1 = (\pi r_2^2)v_2$, which simplifies to $r_1^2 v_1 = r_2^2 v_2$.

Step 3: Apply the given condition.
The radius becomes half, so $r_2 = r_1/2$.
$r_1^2 v_1 = \left(\frac{r_1}{2}\right)^2 v_2$
$r_1^2 v_1 = \frac{r_1^2}{4} v_2$

Step 4: Solve for $v_2$.
$v_1 = \frac{1}{4} v_2 \implies v_2 = 4v_1$.
The speed of water becomes four times.

**Final Answer:** $\boxed{Four \text{ times}}$

**Answer: (C)**

Go Back to Question 7

# Q8.

## Solution

**Concept:** The general equation for a transverse wave traveling along the x-axis is given by $y(x,t) = A\sin(kx - \omega t + \phi)$ or $y(x,t) = A\sin(\omega t - kx + \phi)$. Here, $A$ is the amplitude, $\omega$ is the angular frequency, $k$ is the wave number, and $\phi$ is the phase constant. The wavelength ($\lambda$) is related to the wave number ($k$) by the formula $k = \frac{2\pi}{\lambda}$.

**Solution:** Step 1: Write the given equation of the wave.
The equation is $y = 5\sin(100t - 0.4x)$ SI units.

Step 2: Compare the given equation with the general form of a wave equation.
The general form of a wave traveling in the positive x-direction is $y(x,t) = A\sin(\omega t - kx + \phi)$.
By comparing, we can identify the following:
Amplitude $A = 5$ (units are not specified but are consistent for y).
Angular frequency $\omega = 100$ rad/s.
Wave number $k = 0.4$ rad/m.

Step 3: Use the relationship between wave number and wavelength.
The wave number $k$ is related to the wavelength $\lambda$ by the formula $k = \frac{2\pi}{\lambda}$.

Step 4: Solve for the wavelength ($\lambda$).
Rearrange the formula to solve for $\lambda$:
$\lambda = \frac{2\pi}{k}$
Substitute the value of $k$:
$\lambda = \frac{2\pi}{0.4}$

Step 5: Calculate the numerical value of the wavelength.
$\lambda = \frac{2\pi}{0.4} = \frac{2\pi}{4/10} = \frac{2\pi \times 10}{4} = \frac{20\pi}{4} = 5\pi.$
The wavelength is $5\pi$ meters.

**Final Answer:** $\boxed{5\pi \text{ m}}$

**Answer: (B)**

Go Back to Question 8

# Q9.

## Solution

**Concept:** An open organ pipe is a pipe that is open at both ends. It can resonate at its fundamental frequency (first harmonic) and its overtones (higher harmonics). The fundamental frequency ($f_1$) of an open organ pipe is given by the formula $f_1 = \frac{v}{2L}$, where $v$ is the speed of sound and $L$ is the length of the pipe.

**Solution:** Step 1: Identify the given information.
The organ pipe is open.
The fundamental frequency $f_1 = 200$ Hz.
The speed of sound $v = 340$ m/s.

Step 2: Recall the formula for the fundamental frequency of an open organ pipe.
For an open organ pipe, the fundamental frequency is given by:
$$f_1 = \frac{v}{2L}$$

Step 3: Rearrange the formula to solve for the length of the pipe ($L$).
$$L = \frac{v}{2f_1}$$

Step 4: Substitute the given values into the formula.
$$L = \frac{340 \text{ m/s}}{2 \times 200 \text{ Hz}}$$
$$L = \frac{340 \text{ m/s}}{400 \text{ s}^{-1}}$$

Step 5: Calculate the length of the pipe.
$$L = \frac{340}{400} \text{ m}$$
$$L = \frac{34}{40} \text{ m}$$
$$L = \frac{17}{20} \text{ m}$$
$$L = 0.85 \text{ m.}$$

**Final Answer:** $\boxed{0.85 \text{ m}}$

**Answer: (B)**

Go Back to Question 9

# Q10.

## Solution

**Concept:** For a convex lens, the nature and size of the image formed depend on the position of the object relative to the focal length ($f$) and twice the focal length ($2f$).
- If the object is placed beyond $2f$, the image is real, inverted, and diminished, formed between $f$ and $2f$.
- If the object is placed at $2f$, the image is real, inverted, and of the same size, formed at $2f$.
- If the object is placed between $f$ and $2f$, the image is real, inverted, and magnified, formed beyond $2f$.
- If the object is placed at $f$, the image is formed at infinity.
- If the object is placed within $f$ (between the lens and $f$), the image is virtual, erect, and magnified, formed on the same side as the object.

**Solution:** Step 1: Identify the type of lens and the object's position.
The lens is a convex lens.
The object is placed at twice the focal length, which means the object distance ($u$) is $2f$.

Step 2: Recall the behavior of a convex lens when the object is placed at $2f$.
According to the rules of image formation by a convex lens, when an object is placed at a distance of $2f$ from the optical center, the image formed is:
- Real (can be projected on a screen)
- Inverted (upside down relative to the object)
- Of the same size as the object.
The image is formed at a distance of $2f$ on the other side of the lens.

Step 3: Evaluate the given options based on the image characteristics.
- Virtual and erect: This happens when the object is within the focal length. (Incorrect)
- Real and same size: This matches our conclusion.
- Real and magnified: This happens when the object is between $f$ and $2f$. (Incorrect)
- Virtual and diminished: This does not occur for a convex lens with an object placed at $2f$. (Incorrect)

**Final Answer:** $\boxed{Real \text{ and same size}}$

**Answer: (B)**

Go Back to Question 10

# Q11.

## Solution

**Concept:** Ray diagrams help to determine the nature, position, and size of the image formed by a lens. For a convex lens, a ray passing through the optical center goes undeviated. A ray parallel to the principal axis passes through the principal focus on the other side after refraction. A ray passing through the principal focus on the same side becomes parallel to the principal axis after refraction. The intersection of these rays (or their extensions) determines the image.

**Solution:** Step 1: Analyze the given diagram. The diagram shows a convex lens (implied by the converging effect of rays) and the path of rays from an object.
- An object is shown on the left.
- A ray from the top of the object is shown passing through the optical center of the lens and continuing undeviated.
- An image is shown on the right, formed by the intersection of rays. Since the ray from the object passing through the optical center is shown directly connecting to the image, and the image is on the opposite side of the lens from the object, this indicates a real image.

Step 2: Determine the nature of the image based on the ray diagram.
In the diagram, the ray from the object's top passes through the lens and directly leads to the top of the image. The image is formed on the opposite side of the lens from the object, which is characteristic of a real image formed by a convex lens when the object is placed at a distance greater than the focal length. The drawing implies that the image is inverted relative to the object (though the object's orientation isn't explicitly drawn, the standard convention for lenses implies inversion for real images).

Step 3: Consider the typical scenarios for convex lenses.
Convex lenses can form real, inverted images when the object is placed beyond the focal point. They can form virtual, erect images when the object is placed within the focal point. Since the image is formed on the opposite side of the lens from the object, it is a real image. The diagram suggests inversion, as is typical for real images formed by single lenses.

Step 4: Evaluate the options.
- Virtual and erect: This occurs when the object is within the focal length. The diagram shows the image on the opposite side, so it's not virtual.
- Real and inverted: This is consistent with the image being formed on the opposite side of a convex lens.
- Virtual and diminished: Not consistent with the diagram.
- Real and erect: This doesn't happen for a single convex lens forming a real image.

**Final Answer:** $\boxed{Real \text{ and inverted}}$

**Answer: (B)**

Go Back to Question 11

# Q12.

## Solution

**Concept:** In Young's Double Slit Experiment (YDSE), the fringe width ($\beta$) is the distance between two consecutive bright fringes or two consecutive dark fringes. The formula for fringe width is given by $\beta = \frac{\lambda D}{d}$, where $\lambda$ is the wavelength of the light, $D$ is the distance between the slits and the screen, and $d$ is the distance between the two slits.

**Solution:** Step 1: State the formula for fringe width in YDSE.
The fringe width $\beta$ is given by:
$$\beta = \frac{\lambda D}{d}$$

Step 2: Analyze the effect of changing the distance between the slits.
The question states that the distance between the slits ($d$) is doubled. Let the original distance be $d_1$ and the new distance be $d_2$.
So, $d_1 = d$ and $d_2 = 2d$.
The wavelength of light ($\lambda$) and the distance between the slits and the screen ($D$) are assumed to remain unchanged.

Step 3: Calculate the original fringe width.
Let the original fringe width be $\beta_1$.
$$\beta_1 = \frac{\lambda D}{d}$$

Step 4: Calculate the new fringe width.
Let the new fringe width be $\beta_2$.
$$\beta_2 = \frac{\lambda D}{d_2} = \frac{\lambda D}{2d}$$

Step 5: Compare the new fringe width with the original fringe width.
We can rewrite $\beta_2$ as:
$$\beta_2 = \frac{1}{2}\left(\frac{\lambda D}{d}\right)$$
Since $\beta_1 = \frac{\lambda D}{d}$, we have:
$$\beta_2 = \frac{1}{2}\beta_1.$$

This means the new fringe width is half of the original fringe width.

**Final Answer:** $\boxed{Half}$

**Answer: (B)**

Go Back to Question 12

## Q13.

### Solution

**Concept:** When a charged particle moves in a magnetic field, it experiences a magnetic force given by the Lorentz force formula: $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$. 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 ($\vec{v}$) and the magnetic field ($\vec{B}$). If the velocity is parallel or antiparallel to the magnetic field, the cross product $\vec{v} \times \vec{B}$ is zero, resulting in zero force.

**Solution:** Step 1: Analyze the force acting on a charged particle in a magnetic field.
The magnetic force on a charged particle moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is given by $\vec{F} = q(\vec{v} \times \vec{B})$.

Step 2: Consider the condition given in the problem.
The charged particle enters a uniform magnetic field parallel to the field lines. This means the velocity vector $\vec{v}$ is either in the same direction as $\vec{B}$ or in the opposite direction. Mathematically, the angle $\theta$ between $\vec{v}$ and $\vec{B}$ is $0°$ or $180°$.

Step 3: Evaluate the magnetic force for this condition.
The magnitude of the magnetic force is $F = |q|vB\sin\theta$.
If $\theta = 0°$ or $\theta = 180°$, then $\sin\theta = \sin(0°) = 0$ or $\sin(180°) = 0$.
Therefore, the magnetic force $F = |q|vB \cdot 0 = 0$.

Step 4: Determine the path of the particle when the force is zero.
According to Newton's first law of motion (law of inertia), an object in motion will stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
Since the net magnetic force on the charged particle is zero, its velocity will not change. If it was moving with a constant velocity, it will continue to move with that same constant velocity. This means it will travel in a straight line.

**Final Answer:** $\boxed{Straight \text{ line}}$

**Answer: (C)**

**Go Back to Question 13**

# Q14.

## Solution

**Concept:** The magnetic field at the center of a circular coil of radius $R$ carrying a current $I$ is given by the formula $B = \frac{\mu_0 I}{2R}$, where $\mu_0$ is the permeability of free space. This formula can be derived using the Biot-Savart law. The formula shows how the magnetic field strength depends on the current and the radius.

**Solution:** Step 1: Write down the formula for the magnetic field at the center of a circular coil.
The magnetic field ($B$) at the center of a circular coil with radius $R$ and carrying a current $I$ is given by:
$B = \frac{\mu_0 I}{2R}$

Step 2: Analyze the proportionality of the magnetic field.
We need to determine what the magnetic field is proportional to. From the formula, we can see the terms that affect $B$. The permeability of free space ($\mu_0$) is a constant. The magnetic field $B$ is directly proportional to the current $I$ and inversely proportional to the radius $R$.

Step 3: Express the proportionality mathematically.
$B \propto \frac{I}{R}$

Step 4: Compare with the given options.
Option (A) is $\frac{I}{R}$, which matches our derived proportionality.
Option (B) is $\frac{R}{I}$, which is the inverse.
Option (C) is $IR$, which is a product.
Option (D) is $\frac{1}{IR}$, which is also incorrect.

**Final Answer:** $\boxed{\frac{I}{R}}$

**Answer: (A)**

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# Q15.

## Solution

**Concept:** In the given circuit diagram, the two resistors are connected in parallel between points A and B. For resistors connected in parallel, the reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the individual resistances. The formula for two resistors $R_1$ and $R_2$ in parallel is $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$, which can be simplified to $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$.

**Solution:** Step 1: Identify the components and their arrangement in the circuit.
The circuit consists of two resistors: one with resistance $4\Omega$ and another with resistance $6\Omega$. Both resistors are connected between points A and B. This indicates a parallel connection.

Step 2: Apply the formula for equivalent resistance of parallel resistors.
For resistors in parallel, the equivalent resistance $R_{eq}$ is given by:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Here, $R_1 = 4\Omega$ and $R_2 = 6\Omega$.

Step 3: Substitute the values and calculate.

$$\frac{1}{R_{eq}} = \frac{1}{4\Omega} + \frac{1}{6\Omega}$$

To add these fractions, find a common denominator, which is 12.

$$\frac{1}{R_{eq}} = \frac{3}{12\Omega} + \frac{2}{12\Omega}$$

$$\frac{1}{R_{eq}} = \frac{3+2}{12\Omega} = \frac{5}{12\Omega}$$

Step 4: Find the equivalent resistance by taking the reciprocal.

$$R_{eq} = \frac{12\Omega}{5}$$

$$R_{eq} = 2.4\Omega$$

Alternatively, using the simplified formula for two parallel resistors:

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(4\Omega)(6\Omega)}{4\Omega + 6\Omega} = \frac{24\Omega^2}{10\Omega} = 2.4\Omega.$$

**Final Answer:** $\boxed{2.4\Omega}$

**Answer: (A)**

**Go Back to Question 15**

# Q16.

## Solution

**Concept:** In an alternating current (AC) circuit, the rms (root mean square) value of the current is related to the peak current ($I_p$) by the formula $I_{rms} = \frac{I_p}{\sqrt{2}}$. The rms value is the effective value of the AC current, equivalent to the DC current that would produce the same amount of heat in a resistor.

**Solution:** Step 1: Identify the given information.
The rms value of the alternating current is $I_{rms} = 5$ A.

Step 2: Recall the relationship between rms current and peak current.
The relationship is $I_{rms} = \frac{I_p}{\sqrt{2}}$.

Step 3: Rearrange the formula to solve for the peak current ($I_p$).
$I_p = I_{rms} \times \sqrt{2}$.

Step 4: Substitute the given value of $I_{rms}$ and calculate $I_p$.
$I_p = 5 \text{ A} \times \sqrt{2}$
$I_p = 5\sqrt{2}$ A.

**Final Answer:** $\boxed{5\sqrt{2} \text{ A}}$

**Answer: (A)**

Go Back to Question 16

# Q17.

## Solution

**Concept:** Semiconductors are materials whose conductivity lies between that of a conductor and an insulator. Pure semiconductors (like silicon or germanium) are intrinsic. To increase their conductivity, they are doped with impurities. Doping with pentavalent impurities (like phosphorus, arsenic, antimony) creates n-type semiconductors, where the majority charge carriers are electrons. Doping with trivalent impurities (like boron, aluminum, gallium) creates p-type semiconductors, where the majority charge carriers are holes.

**Solution:** Step 1: Understand the concept of doping in semiconductors.
Doping is the process of adding impurity atoms to an intrinsic semiconductor to alter its electrical properties.

Step 2: Recall the valency of common dopants and their effect on silicon.
Silicon (Si) is in Group 14 of the periodic table and has 4 valence electrons.
- Pentavalent impurities (Group 15) have 5 valence electrons. When doped into silicon, four electrons form covalent bonds with silicon atoms, and the fifth electron is loosely bound and can move freely, acting as a charge carrier. This results in an n-type semiconductor. Examples: Phosphorus (P), Arsenic (As), Antimony (Sb).
- Trivalent impurities (Group 13) have 3 valence electrons. When doped into silicon, these atoms form covalent bonds with silicon atoms, but one bond is incomplete, creating a "hole" where an electron should be. This hole can accept an electron, effectively acting as a positive charge carrier. This results in a p-type semiconductor. Examples: Boron (B), Aluminum (Al), Gallium (Ga).

Step 3: Identify the type of semiconductor formed by doping silicon with the given elements.
- Phosphorus: Pentavalent, forms n-type semiconductor.
- Arsenic: Pentavalent, forms n-type semiconductor.
- Boron: Trivalent, forms p-type semiconductor.
- Germanium: This is another semiconductor material, not an impurity dopant for silicon in this context.

Step 4: Choose the dopant that forms a p-type semiconductor.
Boron is a trivalent impurity. Doping silicon with boron creates a p-type semiconductor.

**Final Answer:** $\boxed{Boron}$

**Answer: (C)**

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# Q18.

## Solution

**Concept:** In the photoelectric effect, the maximum kinetic energy of emitted electrons is given by Einstein's equation:

$$KE_{max} = hf - \phi$$

where $h$ is Planck's constant, $f$ is the frequency of incident light, and $\phi$ is the work function of the metal. The stopping potential $V_s$ is related to the maximum kinetic energy by:

$$KE_{max} = eV_s$$

Combining the two equations:

$$V_s = \frac{hf - \phi}{e}$$

Hence, the stopping potential depends on the frequency of incident light and the work function of the material.

**Solution:** From Einstein's photoelectric equation,

$$KE_{max} = hf - \phi$$

Also,

$$KE_{max} = eV_s$$

Equating,

$$eV_s = hf - \phi$$

Therefore,

$$V_s = \frac{hf - \phi}{e}$$

This shows that the stopping potential increases with frequency of incident light and also depends on the work function of the metal.

The intensity of light affects only the number of emitted electrons, not the stopping potential. Distance from the source also does not directly affect $V_s$.

Thus, among the given options, the most appropriate choice is frequency only.

**Final Answer:** Frequency only

**Answer: (B)**

Go Back to Question 18

# Q19.

## Solution

**Concept:** Binding energy per nucleon is a measure of the stability of a nucleus. It represents the average energy required to remove one nucleon (proton or neutron) from the nucleus. Generally, nuclei with higher binding energy per nucleon are more stable. The binding energy per nucleon graph as a function of mass number shows a peak around iron ($^{56}$Fe). Nuclei lighter than iron generally have lower binding energy per nucleon and increase towards iron, while nuclei heavier than iron generally have lower binding energy per nucleon and decrease away from iron.

**Solution:** Step 1: Understand the concept of binding energy per nucleon.
The binding energy per nucleon is the total binding energy of a nucleus divided by the number of nucleons (protons + neutrons) in the nucleus. It indicates the stability of the nucleus. A higher binding energy per nucleon means a more stable nucleus.

Step 2: Recall the trend of binding energy per nucleon with mass number.
The binding energy per nucleon curve starts low for light nuclei, rises to a maximum around mass number $A \approx 56$ (isotopes of iron, like $^{56}$Fe), and then gradually decreases for heavier nuclei.

Step 3: Identify the element that corresponds to the peak of the binding energy curve.
The peak of the binding energy per nucleon curve is around mass number 56. This peak is most pronounced for isotopes of iron (Fe), particularly Iron-56 ($^{56}$Fe).

Step 4: Evaluate the stability of the given options.
- Hydrogen (H): Very light nucleus, low binding energy per nucleon.
- Helium (He): Light nucleus, higher binding energy per nucleon than hydrogen, but still on the rising part of the curve.
- Iron (Fe): Located at or very near the peak of the binding energy curve, indicating maximum stability.
- Uranium (U): Very heavy nucleus, on the descending part of the curve, less stable than iron.

Step 5: Conclude which element has the maximum binding energy per nucleon.
Iron has the highest binding energy per nucleon among the given options, signifying the greatest nuclear stability.

**Final Answer:** $\boxed{Iron}$

**Answer: (C)**

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# Q20.

## Solution

**Concept:** Logic gates are fundamental building blocks of digital circuits. A NAND gate is a universal logic gate that performs logical conjunction (AND) followed by logical negation (NOT). Its output is LOW (0) if and only if all of its inputs are HIGH (1); otherwise, its output is HIGH (1). If $A$ and $B$ are the inputs, the Boolean expression for a NAND gate is represented as $\overline{A \cdot B}$ or $\overline{AB}$.

**Solution:** Step 1: Understand the operation of a NAND gate.
A NAND gate has two or more inputs and one output. The output is the inverse of the output of an AND gate.
The operation of an AND gate is $A \cdot B$ (logical AND).
The operation of a NOT gate is $\overline{\text{input}}$ (logical negation).

Step 2: Combine the operations of AND and NOT for a NAND gate.
A NAND gate performs the AND operation on its inputs and then negates the result.
So, if the inputs are $A$ and $B$, the output $Y$ is given by:
$Y = \overline{A \cdot B}$
This is often written as $Y = \overline{AB}$.

Step 3: Compare the derived expression with the given options.
- Option (A) $A + B$: This is the Boolean expression for an OR gate.
- Option (B) $\overline{AB}$: This matches our derived expression for a NAND gate.
- Option (C) $\overline{A + B}$: This is the Boolean expression for a NOR gate.
- Option (D) $AB$: This is the Boolean expression for an AND gate.

**Final Answer:** $\boxed{\overline{AB}}$

**Answer: (B)**

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# Q21.

## Solution

**Concept:** The range ($R$) of a projectile is the horizontal distance it travels before returning to the same vertical level from which it was launched. For a projectile launched with an initial velocity $v_0$ at an angle of projection $\theta$ with the horizontal, the range is given by the formula $R = \frac{v_0^2 \sin(2\theta)}{g}$, where $g$ is the acceleration due to gravity. To achieve the maximum range, the value of $\sin(2\theta)$ must be maximum.

**Solution:** Step 1: Write down the formula for the range of a projectile.
The horizontal range $R$ of a projectile launched with initial velocity $v_0$ at an angle $\theta$ with the horizontal is:

$$R = \frac{v_0^2 \sin(2\theta)}{g}$$

Step 2: Identify the condition for maximum range.
To maximize the range $R$, we need to maximize the term $\sin(2\theta)$, as $v_0$ and $g$ are constants for a given projectile.

Step 3: Determine the angle $\theta$ for which $\sin(2\theta)$ is maximum.
The maximum value of the sine function is 1.
So, we need $\sin(2\theta) = 1$.
This occurs when $2\theta = 90^\circ$.

Step 4: Solve for the angle of projection $\theta$.

$$2\theta = 90^\circ$$
$$\theta = \frac{90^\circ}{2}$$
$$\theta = 45^\circ.$$

Step 5: Conclude the angle for maximum range.
The maximum range of a projectile occurs at an angle of projection of $45^\circ$.

**Final Answer:** $\boxed{45^\circ}$

**Answer: (B)**

**Go Back to Question 21**

# Q22.

## Solution

**Concept:** Kinetic energy ($KE$) of a body of mass $m$ and momentum $p$ is given by $KE = \frac{1}{2}mv^2$. Momentum is given by $p = mv$. We can relate kinetic energy and momentum by substituting $v = p/m$ into the kinetic energy formula: $KE = \frac{1}{2}m\left(\frac{p}{m}\right)^2 = \frac{1}{2}m\frac{p^2}{m^2} = \frac{p^2}{2m}$. This formula shows that kinetic energy is proportional to the square of momentum, $KE \propto p^2$.

**Solution:** Step 1: Write down the formulas for kinetic energy and momentum.
Kinetic energy: $KE = \frac{1}{2}mv^2$
Momentum: $p = mv$

Step 2: Express kinetic energy in terms of momentum.
From the momentum formula, $v = \frac{p}{m}$.
Substitute this into the kinetic energy formula:
$KE = \frac{1}{2}m\left(\frac{p}{m}\right)^2 = \frac{1}{2}m\frac{p^2}{m^2} = \frac{p^2}{2m}$.

Step 3: Analyze the relationship between kinetic energy and momentum.
The relationship is $KE = \frac{p^2}{2m}$. This means $p^2 = 2m \cdot KE$, or $p = \sqrt{2m \cdot KE}$.
Therefore, momentum $p$ is proportional to the square root of kinetic energy: $p \propto \sqrt{KE}$.

Step 4: Apply the given condition.
The kinetic energy of the body becomes four times its initial value.
Let the initial kinetic energy be $KE_1$ and the initial momentum be $p_1$.
$p_1 \propto \sqrt{KE_1}$.
Let the final kinetic energy be $KE_2$ and the final momentum be $p_2$.
We are given $KE_2 = 4KE_1$.

Step 5: Calculate the new momentum.
Using the proportionality $p \propto \sqrt{KE}$:
$p_2 \propto \sqrt{KE_2} = \sqrt{4KE_1} = \sqrt{4}\sqrt{KE_1} = 2\sqrt{KE_1}$.
Since $p_1 \propto \sqrt{KE_1}$, we can say that $p_2$ is twice the value of $p_1$.
$p_2 = 2p_1$.

So, the momentum becomes double.

**Final Answer:** $\boxed{Double}$

**Answer: (A)**

Go Back to Question 22

# Q23.

## Solution

**Concept:** Stress is a measure of the internal forces that particles within a continuous material exert on each other. It is defined as the force acting per unit area of a material. In mechanics, when an external force is applied to an object, the object develops internal restoring forces that resist the deformation. Stress is the measure of these internal restoring forces acting over a unit cross-sectional area.

**Solution:** Step 1: Define stress in the context of material mechanics.
Stress is a physical quantity that describes the internal forces that particles within a continuous material exert on each other. It quantifies how much the material is being deformed under applied forces.

Step 2: State the mathematical definition of stress.
Stress ($\sigma$ or $\tau$) is defined as the force ($F$) applied per unit area ($A$) over which the force is distributed.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

Step 3: Compare this definition with the given options.
- Option (A) Force × Area: This would be related to work or energy.
- Option (B) Force / Area: This matches the definition of stress.
- Option (C) Area / Force: This is the reciprocal of stress.
- Option (D) Force × Length: This is related to work.

**Final Answer:** Force / Area

**Answer: (B)**

Go Back to Question 23

# Q24.

## Solution

**Concept:** When capacitors are connected in series, the reciprocal of the equivalent capacitance is equal to the sum of the reciprocals of the individual capacitances. For two capacitors $C_1$ and $C_2$ connected in series, the equivalent capacitance $C_{eq}$ is given by the formula $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$. This can be simplified to $C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$.

**Solution:** Step 1: Identify the given capacitances and their connection.
We have two capacitors with capacitances $C_1 = 3\,\mu F$ and $C_2 = 6\,\mu F$.
They are connected in series.

Step 2: Apply the formula for equivalent capacitance of capacitors in series.
The formula for the equivalent capacitance of two capacitors in series is:
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Step 3: Substitute the given values into the formula.
$$\frac{1}{C_{eq}} = \frac{1}{3\,\mu F} + \frac{1}{6\,\mu F}$$

Step 4: Find a common denominator to add the fractions.
The least common denominator for 3 and 6 is 6.
$$\frac{1}{C_{eq}} = \frac{2}{6\,\mu F} + \frac{1}{6\,\mu F}$$
$$\frac{1}{C_{eq}} = \frac{2+1}{6\,\mu F} = \frac{3}{6\,\mu F}$$

Step 5: Simplify the fraction and find $C_{eq}$.
$$\frac{1}{C_{eq}} = \frac{1}{2\,\mu F}$$
Taking the reciprocal of both sides:
$C_{eq} = 2\,\mu F$.

Alternatively, using the simplified formula for two capacitors in series:
$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{(3\,\mu F)(6\,\mu F)}{3\,\mu F + 6\,\mu F} = \frac{18\,(\mu F)^2}{9\,\mu F} = 2\,\mu F.$$

**Final Answer:** $\boxed{2\mu F}$

**Answer: (A)**

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# Q25.

## Solution

**Concept:** The mirror formula relates the object distance ($u$), image distance ($v$), and focal length ($f$) of a spherical mirror. For a concave mirror, the mirror formula is $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$. Sign conventions are crucial: focal length ($f$) is negative for a concave mirror. Object distance ($u$) is usually taken as negative if measured against the direction of incident light (which is the convention in most setups). Image distance ($v$) is negative for a real image (formed in front of the mirror) and positive for a virtual image (formed behind the mirror).

**Solution:** Step 1: Identify the type of mirror and its focal length.
The mirror is concave. The focal length $f = 20$ cm.
According to the sign convention for concave mirrors, $f = -20$ cm.

Step 2: Identify the object distance.
The object is placed at 40 cm from the mirror.
According to the sign convention, the object distance $u = -40$ cm.

Step 3: Apply the mirror formula.
The mirror formula is $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$.

Step 4: Substitute the known values and solve for the image distance ($v$).

$$\frac{1}{-20} = \frac{1}{v} + \frac{1}{-40}$$
$$\frac{1}{v} = \frac{1}{-20} - \frac{1}{-40}$$
$$\frac{1}{v} = \frac{1}{-20} + \frac{1}{40}$$

Step 5: Find a common denominator and calculate.
The common denominator is 40.

$$\frac{1}{v} = \frac{-2}{40} + \frac{1}{40}$$
$$\frac{1}{v} = \frac{-2+1}{40} = \frac{-1}{40}$$

Step 6: Find the image distance $v$.
$v = -40$ cm.

The negative sign for $v$ indicates that the image is formed in front of the mirror, which means it is a real image. The image distance is 40 cm.

**Final Answer:** 40 cm

**Answer: (C)**

Go Back to Question 25

## Q26.

### Solution

**Concept:** Fleming's Left-Hand Rule determines the direction of force on a current-carrying conductor in a magnetic field. The thumb, forefinger, and middle finger represent Force, Magnetic Field, and Current, respectively, and are mutually perpendicular.

**Solution:** Step 1: Identify the directions of current ($I$) and magnetic field ($B$) from the diagram.
$I$ is shown horizontally to the right (let's assume along the x-axis).
$B$ is shown vertically upwards (let's assume along the y-axis).

Step 2: Apply Fleming's Left-Hand Rule.
- Point the middle finger in the direction of current (to the right).
- Point the forefinger in the direction of the magnetic field (upwards).
- The thumb will then point in the direction of the force.

Step 3: Determine the direction of the force.
Following the rule, the thumb points into the plane of the diagram (along the negative z-axis).

**Final Answer:** $\boxed{\textit{Into} \text{ the plane}}$

**Answer: (A)**

**Go Back to Question 26**

## Q27.

### Solution

**Concept:** The energy of a photon is given by Planck's equation: $E = hf$, where $h$ is Planck's constant and $f$ is the frequency. This means energy is directly proportional to frequency.

**Solution:** Step 1: State Planck's equation.
$E = hf$.

Step 2: Analyze the proportionality.
From the equation, $E \propto f$. The energy of a photon is directly proportional to its frequency.

Step 3: Consider the other options.
- Wavelength: $E = hc/\lambda$, so energy is inversely proportional to wavelength.
- Square of frequency: Energy is proportional to frequency, not its square.
- Velocity: Velocity of light is a constant.

**Final Answer:** $\boxed{Frequency}$

**Answer: (B)**

**Go Back to Question 27**

## Q28.

### Solution

**Concept:** The total energy ($E$) of a particle in SHM is given by $E = \frac{1}{2}kA^2$, where $k$ is the spring constant and $A$ is the amplitude. Since $k = m\omega^2$, $E = \frac{1}{2}m\omega^2A^2$.

**Solution:** Step 1: Write the formula for total energy in SHM.
$E = \frac{1}{2}kA^2$.

Step 2: Analyze the proportionality.
The total energy $E$ is directly proportional to the square of the amplitude $A$.
$E \propto A^2$.

**Final Answer:** $\boxed{Square \text{ of amplitude}}$

**Answer: (B)**

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## Q29.

### Solution

**Concept:** An adiabatic process is a thermodynamic process in which no heat is transferred into or out of the system ($\Delta Q = 0$). The first law of thermodynamics is $\Delta U = \Delta Q - W$.

**Solution:** Step 1: Define adiabatic process.
An adiabatic process is one where $\Delta Q = 0$.

Step 2: Apply the first law of thermodynamics.
$\Delta U = \Delta Q - W$.
For an adiabatic process, $\Delta U = 0 - W = -W$.

Step 3: Conclude the correct condition.
The defining characteristic of an adiabatic process is $\Delta Q = 0$.

**Final Answer:** $\boxed{\Delta Q = 0}$

**Answer: (A)**

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# Q30.

## Solution

**Concept:** The Doppler effect states that the apparent frequency of a sound wave changes due to the relative motion between the source and the observer. The apparent frequency increases when the source and observer are moving closer to each other.

**Solution:** Step 1: Understand the Doppler effect.
Relative motion between source and observer changes the observed frequency.

Step 2: Determine the condition for increased apparent frequency.
Apparent frequency increases when the distance between the source and observer is decreasing. This happens when they move towards each other.

Step 3: Evaluate the options.
- Source moves away: Distance increases, frequency decreases.
- Observer moves away: Distance increases, frequency decreases.
- Source approaches observer: Distance decreases, frequency increases.
- Both move away: Distance increases, frequency decreases.

**Final Answer:** $\boxed{Source \text{ approaches observer}}$

**Answer: (C)**

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# Q31.

## Solution

**Concept:** Electric field lines represent the direction of the electric field. At any point, the electric field vector is tangent to the electric field line at that point. Since a vector can only have one direction at a point, electric field lines cannot intersect.

**Solution:** Step 1: Recall the meaning of electric field lines.
Electric field lines show the direction of the electric field. The tangent to a field line at any point gives the direction of the electric field at that point.

Step 2: Consider the implication of intersecting lines.
If two electric field lines intersected at a point, it would imply that the electric field has two different directions at that single point, which is physically impossible.

Step 3: Evaluate the options.
- Field is scalar: Electric field is a vector.
- Two tangents cannot exist at one point: This is the correct reasoning. If lines intersect, there would be two tangents, hence two directions for the field.
- Charges are discrete: This is true but not the reason for non-intersection.
- Potential is constant: Potential is related but not the direct reason.

**Final Answer:** $\boxed{Two \text{ tangents cannot exist at one point}}$

**Answer: (B)**

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## Q32.

### Solution

**Concept:** In a p-n junction diode, the depletion layer is the region around the junction depleted of mobile charge carriers. When a reverse bias voltage is applied, it opposes the internal electric field, causing the depletion layer to widen.

**Solution:** Step 1: Understand the depletion layer.
The depletion layer is formed at the p-n junction due to the diffusion of majority carriers, leaving immobile ions behind.

Step 2: Analyze the effect of reverse bias.
Reverse bias applies an external voltage that opposes the internal electric field. This forces majority carriers further away from the junction.

Step 3: Conclude the effect on the depletion layer.
The outward movement of majority carriers causes the depletion layer to widen.

**Final Answer:** $\boxed{Increases}$

**Answer: (C)**

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## Q33.

### Solution

**Concept:** After one half-life ($t_{1/2}$), half of the radioactive nuclei decay, leaving $N_0/2$ undecayed nuclei. After two half-lives, half of the remaining nuclei decay, leaving $(N_0/2)/2 = N_0/4$ undecayed nuclei.

**Solution:** Step 1: Understand half-life.
After one half-life, the number of undecayed nuclei is halved.

Step 2: Calculate the number of undecayed nuclei after two half-lives.
Let $N_0$ be the initial number of undecayed nuclei.
After 1 half-life: $N_1 = N_0 \times \frac{1}{2}$.
After 2 half-lives: $N_2 = N_1 \times \frac{1}{2} = \left(\frac{N_0}{2}\right) \times \frac{1}{2} = \frac{N_0}{4}$.

**Final Answer:** $\boxed{\frac{N_0}{4}}$

**Answer: (B)**

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# Q34.

## Solution

**Concept:** Centripetal acceleration ($a_c$) is the acceleration required to keep an object moving in a circular path. It is always directed towards the center of the circle. The formula for centripetal acceleration is $a_c = \frac{v^2}{r}$, where $v$ is the speed of the object and $r$ is the radius of the circular path.

**Solution:** Step 1: Write down the formula for centripetal acceleration.
The centripetal acceleration ($a_c$) of an object moving in a circle of radius $r$ with speed $v$ is given by:

$$a_c = \frac{v^2}{r}$$

Step 2: Analyze the proportionality.
From the formula, we can see that the centripetal acceleration $a_c$ is directly proportional to the square of the velocity ($v^2$), and inversely proportional to the radius ($r$).
$a_c \propto v^2$ (assuming $r$ is constant).

Step 3: Compare with the given options.
- $v$: The acceleration is proportional to $v^2$, not $v$.
- $v^2$: This matches our derived proportionality.
- $\frac{1}{v}$: This is inversely proportional to $v$.
- $\sqrt{v}$: This is proportional to the square root of $v$.

**Final Answer:** $\boxed{v^2}$

**Answer: (B)**

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# Q35.

## Solution

**Concept:** Diffraction is the phenomenon where waves spread out as they pass through an opening or around an obstacle. The extent of diffraction is most significant when the size of the opening or obstacle is comparable to the wavelength of the wave. When the slit width is close to the wavelength, the spreading of the wave is most pronounced, and the diffraction effects become prominent.

**Solution:** Step 1: Define diffraction.
Diffraction is the bending and spreading of waves when they encounter an obstacle or pass through an aperture.

Step 2: Relate diffraction to wavelength and obstacle/aperture size.
The degree of diffraction depends on the ratio of the wavelength of the wave ($\lambda$) to the size of the opening or obstacle ($d$).
- If $d \gg \lambda$, diffraction is negligible.
- If $d \approx \lambda$, diffraction effects are most prominent.
- If $d \ll \lambda$, the wave spreads out significantly, acting like a point source.

Step 3: Determine the condition for prominent diffraction effects.
Diffraction effects become prominent when the size of the slit (or obstacle) is comparable to the wavelength of the light. This means the slit width should be approximately equal to the wavelength.

Step 4: Evaluate the given options.
- Very large: Diffraction is negligible.
- Equal to wavelength: This is the condition for prominent diffraction.
- Infinite: Diffraction is not applicable.
- Zero: Diffraction is not applicable.

**Final Answer:** $\boxed{Equal \text{ to wavelength}}$

**Answer: (B)**

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## Q36.

### Solution

**Concept:** Wave nature of light is demonstrated by phenomena where light exhibits characteristics like interference, diffraction, and polarization. The photoelectric effect, conversely, demonstrates the particle nature of light (photons).

**Solution:** Step 1: Evaluate each phenomenon in relation to the wave nature of light.
- Interference: This occurs when two or more waves overlap, resulting in constructive or destructive interference patterns. It is a hallmark of wave behavior. Thus, Interference demonstrates the wave nature of light.
- Diffraction: This is the bending of waves as they pass through an opening or around an obstacle. It is a wave phenomenon. Thus, Diffraction demonstrates the wave nature of light.
- Polarization: This refers to the orientation of the oscillations of the transverse wave. It can only occur for transverse waves, demonstrating the transverse nature of light waves. Thus, Polarization demonstrates the wave nature of light.
- Photoelectric effect: This phenomenon, where electrons are emitted from a metal surface when light shines on it, is explained by considering light as discrete packets of energy (photons), thus demonstrating the particle nature of light.

Step 2: Identify the phenomena demonstrating wave nature.
Interference, diffraction, and polarization all demonstrate the wave nature of light.

**Final Answer:** $\boxed{A, B, C}$

**Answer: (A,B,C)**

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# Q37.

## Solution

**Concept:** In a series LCR circuit, resonance occurs when the inductive reactance ($X_L$) equals the capacitive reactance ($X_C$). At resonance, the impedance ($Z$) of the circuit is minimum and equal to the resistance ($R$), and the current ($I$) is maximum. The power factor ($\cos\phi$) is also unity.

**Solution:** Step 1: Analyze the conditions at resonance in a series LCR circuit.
At resonance, the angular frequency $\omega$ is such that $X_L = X_C$.
$X_L = \omega L$ and $X_C = \frac{1}{\omega C}$.
So, $\omega L = \frac{1}{\omega C}$, which means $\omega^2 = \frac{1}{LC}$.

Step 2: Evaluate each statement.
- Statement (A): "Impedance is minimum". The impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$. At resonance, $X_L = X_C$, so $X_L - X_C = 0$. Thus, $Z = \sqrt{R^2} = R$. Since $R$ is usually much smaller than $X_L$ or $X_C$ at other frequencies, impedance is minimum at resonance. This statement is correct.
- Statement (B): "Current is maximum". The current $I = V/Z$. Since impedance $Z$ is minimum at resonance, the current $I$ is maximum. This statement is correct.
- Statement (C): "Power factor is unity". The power factor is $\cos\phi = R/Z$. At resonance, $Z = R$, so $\cos\phi = R/R = 1$. This statement is correct.
- Statement (D): "Inductive reactance equals capacitive reactance". This is the defining condition for resonance in an LCR circuit. This statement is correct.

Step 3: Identify all correct statements.
Statements (A), (B), (C), and (D) are all correct for a series LCR circuit at resonance.

**Final Answer:** $\boxed{A, B, C, D}$

**Answer: (A,B,C,D)**

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# Q38.

## Solution

**Concept:** In the photoelectric effect, electrons are emitted from a metal surface when light of sufficient frequency shines on it.
- Emission is instantaneous: The emission of photoelectrons occurs almost instantaneously upon illumination, as the photon energy is directly absorbed by an electron.
- Kinetic energy depends on frequency: According to Einstein's photoelectric equation ($KE_{max} = hf - \phi$), the maximum kinetic energy of the emitted electrons is linearly dependent on the frequency ($f$) of the incident light and independent of its intensity.
- Number of electrons depends on intensity: Higher intensity of light means more photons per unit time, leading to more electron emissions per unit time, thus increasing the photocurrent.
- Threshold frequency depends on intensity: The threshold frequency ($f_0 = \phi/h$) is a property of the metal and depends on its work function ($\phi$), not on the intensity of the incident light.

**Solution:** Step 1: Evaluate each statement.
- Statement (A): "Emission of electrons is instantaneous". Experimental evidence shows that the emission of photoelectrons is virtually instantaneous (within $10^{-9}$ seconds) after the light strikes the surface, provided the frequency is above the threshold. This statement is correct.
- Statement (B): "Kinetic energy of emitted electrons depends on frequency". Einstein's photoelectric equation ($KE_{max} = hf - \phi$) shows that the maximum kinetic energy is a linear function of the frequency of incident light. This statement is correct.
- Statement (C): "Number of emitted electrons depends on intensity". The intensity of light is related to the number of photons incident per unit area per unit time. More photons mean more electrons can be ejected (assuming sufficient frequency), so the number of emitted electrons (and hence the photoelectric current) is directly proportional to the intensity. This statement is correct.
- Statement (D): "Threshold frequency depends on intensity". The threshold frequency is determined by the work function of the metal ($\phi$), which is a material property. It is independent of the intensity of the incident light. This statement is incorrect.

Step 2: Identify all correct statements.
Statements (A), (B), and (C) are correct.

**Final Answer:** $\boxed{A, B, C}$

**Answer: (A,B,C)**

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# Q39.

## Solution

**Concept:** A p-n junction diode is a semiconductor device.

- Forward Bias: When the p-type region is at a higher potential than the n-type region, the diode is forward-biased. The applied voltage opposes the internal potential barrier, reducing the depletion layer width and allowing current to flow easily.
- Depletion Layer: In forward bias, the majority carriers from both sides are pushed towards the junction, recombining and reducing the depletion region. In reverse bias, majority carriers are pulled away, widening the depletion region.
- Reverse Bias: When the n-type region is at a higher potential than the p-type region, the diode is reverse-biased. The applied voltage aids the internal potential barrier, widening the depletion layer and restricting current flow (only a small reverse saturation current due to minority carriers).
- Behavior: A diode acts as a conductor in forward bias (low resistance) and an insulator in reverse bias (high resistance), except for a small leakage current.

**Solution:** Step 1: Evaluate each statement about a p-n junction diode.

- Statement (A): "It allows current easily in forward bias". In forward bias, the resistance of the diode is low, allowing significant current flow. This statement is correct.
- Statement (B): "Depletion layer decreases in forward bias". In forward bias, the applied voltage reduces the potential barrier and causes majority carriers to move towards the junction, effectively narrowing the depletion layer. This statement is correct.
- Statement (C): "Reverse current is usually small". In reverse bias, only a small current due to minority carriers flows. This is known as the reverse saturation current, which is typically very small (in the order of microamperes or nanoamperes). This statement is correct.
- Statement (D): "It behaves as an insulator in forward bias". In forward bias, the diode conducts current easily and behaves like a conductor (with a small forward voltage drop), not an insulator. This statement is incorrect.

Step 2: Identify all correct statements.
Statements (A), (B), and (C) are correct.

**Final Answer:** $\boxed{A, B, C}$

**Answer: (A,B,C)**

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# Q40.

## Solution

**Concept:** A charged particle moving in a uniform magnetic field experiences a magnetic force given by $\vec{F} = q(\vec{v} \times \vec{B})$. If the velocity $\vec{v}$ is perpendicular to the magnetic field $\vec{B}$, the force is $F = |q|vB$, and this force is always directed perpendicular to both $\vec{v}$ and $\vec{B}$. This perpendicular force causes the particle to move in a circular path.

- Work done by magnetic force: Since the magnetic force is always perpendicular to the velocity, it does no work on the particle ($W = \vec{F} \cdot \vec{d} = Fd\cos(90^\circ) = 0$).
- Speed: As no work is done, the kinetic energy ($KE = \frac{1}{2}mv^2$) remains constant. Since mass $m$ is constant, the speed $v$ must also remain constant.
- Path: For constant speed and a force always perpendicular to velocity, the path is a circle. The radius of this circle is $r = \dfrac{mv}{|q|B}$.

**Solution:** Step 1: Evaluate each statement.
- Statement (A): "Magnetic force acts on the particle". Since the particle is charged and moving in a magnetic field, a magnetic force acts on it, provided $v$ is not parallel to $B$. Here, $v$ is perpendicular to $B$. This statement is correct.
- Statement (B): "Speed of the particle remains constant". The magnetic force is always perpendicular to the velocity. Therefore, it does no work on the particle, and its kinetic energy remains constant. Since kinetic energy is $\frac{1}{2}mv^2$, and mass is constant, the speed must also remain constant. This statement is correct.
- Statement (C): "Path of the particle is circular". With constant speed and a force always perpendicular to velocity, the particle moves in a circular path. This statement is correct.
- Statement (D): "Work done by magnetic force is non-zero". The magnetic force is always perpendicular to the velocity ($\vec{F} \perp \vec{v}$). The work done is $W = \vec{F} \cdot \vec{d}$, where $\vec{d}$ is the displacement. Since $\vec{d}$ is along the direction of velocity, $\vec{F} \perp \vec{d}$. Therefore, the work done by the magnetic force is $W = Fd\cos(90^\circ) = 0$. This statement is incorrect.

Step 2: Identify all correct statements.
Statements (A), (B), and (C) are correct.

**Final Answer:** $\boxed{A, B, C}$

**Answer: (A,B,C)**

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# Answer Key

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