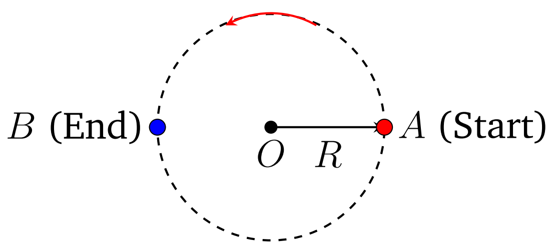
# JEECUP Group A Physics Sample Paper – 13

**Duration: 45 Minutes** **Maximum Marks: 100**

## Instructions

- This paper contains **25** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**. No marks will be deducted for incorrect answers. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

**Q1.** A particle moves along a circular path of radius $R$. If it completes two and a half revolutions, what is the ratio of the total distance covered to the magnitude of its displacement?




(A) $5\pi$

(B) $\frac{5\pi}{2}$

(C) $2\pi$

(D) $\frac{\pi}{5}$

**Q2.** An electrical appliance rated $220$ V, $100$ W is operated at $110$ V. What will be the actual power consumed by the appliance?

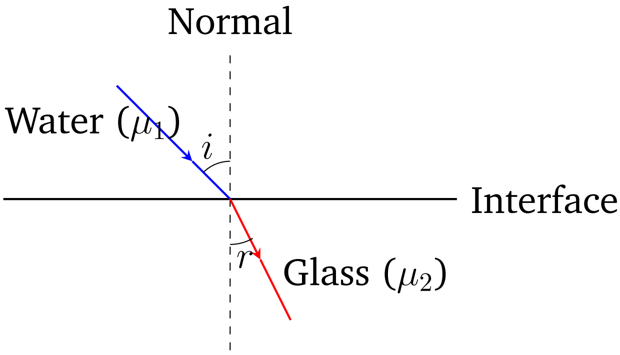
(A) $50$ W

(B) $25$ W

(C) $75$ W

(D) $100$ W

**Q3.** A ray of light passes from water (refractive index $= \frac{4}{3}$) into a glass slab (refractive index $= \frac{3}{2}$). What is the refractive index of glass with respect to water?



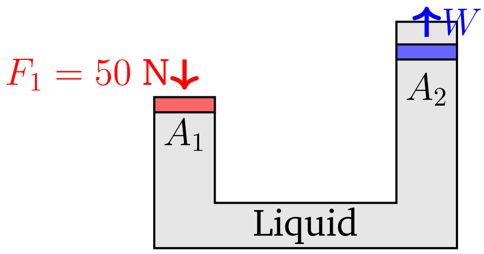

(A) $\frac{8}{9}$

(B) $\frac{9}{8}$

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

(D) 2

**Q4.** A hydraulic lift has a small piston of cross-sectional area $0.02\ \text{m}^2$ and a large piston of area $0.8\ \text{m}^2$. If a force of $50\ \text{N}$ is applied to the small piston, what is the maximum weight it can lift on the larger piston?




(A) $2000\ \text{N}$

(B) $1000\ \text{N}$

(C) $40\ \text{N}$

(D) $250\ \text{N}$

**Q5.** A bullet of mass $20$ g moving with a speed of $150$ m/s penetrates a sand-bag and comes to rest in $0.03$ s. Find the magnitude of the average retarding force acting on the bullet?

(A) 100 N

(B) 200 N

(C) 300 N

(D) 600 N

**Q6.** A radioactive sample has a half-life of 4 hours. If the initial mass of the sample is 100 g, what mass of the sample will remain undecayed after 12 hours?

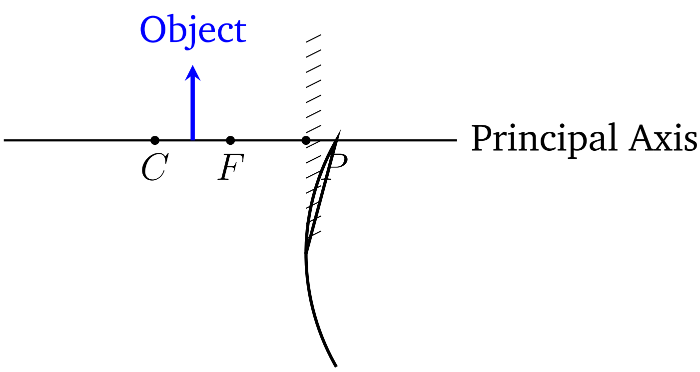
(A) 50 g

(B) 25 g

(C) 12.5 g

(D) 6.25 g

**Q7.** An object is placed at a distance of 15 cm in front of a concave mirror of focal length 10 cm. At what distance from the mirror should a screen be placed to get a sharp image?




(A) $-30$ cm

(B) $-6$ cm

(C) $+30$ cm

(D) $+15$ cm

**Q8.** A body of mass 2 kg is dropped from a tower of height 40 m. Find its kinetic energy when it is exactly halfway down. (Take $g = 10$ m/s$^2$ and neglect air resistance)

(A) 800 J

(B) 400 J

(C) 200 J

(D) 1600 J

**Q9.** A sound wave has a frequency of $2$ kHz and a wavelength of $35$ cm. How long will it take to travel a distance of $1.4$ km?

(A) $2$ s

(B) $4$ s

(C) $0.5$ s

(D) $1$ s

**Q10.** A uniform wire of resistance $R$ is stretched uniformly to double its original length. What will be its new resistance?

(A) $2R$

(B) $4R$

(C) $\frac{R}{2}$

(D) $\frac{R}{4}$

**Q11.** At what temperature do the Celsius and Fahrenheit scales show the exact same numerical reading?

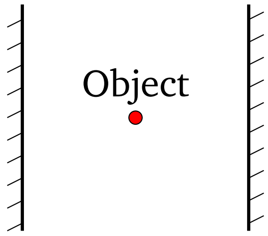
(A) $40^\circ$

(B) $-40^\circ$

(C) $0^\circ$

(D) $-32^\circ$

**Q12.** An object is placed between two parallel plane mirrors facing each other. What is the total number of images formed?




(A) 2

(B) 4

(C) 8

(D) Infinite

**Q13.** A machine does 1800 J of work in 1 minute. What is the power output of the machine?

(A) 1800 W

(B) 300 W

(C) 30 W

(D) 60 W

**Q14.** An electric iron draws a current of 5 A from a 220 V supply line. Calculate the total electrical energy consumed by it if it is used daily for 2 hours over a period of 30 days.

(A) 66 kWh

(B) 2.2 kWh

(C) 1.1 kWh

(D) 33 kWh

**Q15.** A truck and a car are moving with the same kinetic energy. If equal braking forces are applied to both, and they come to a stop after traveling distances $d_1$ and $d_2$ respectively, which of the following relationships is correct?

(A) $d_1 > d_2$

(B) $d_1 < d_2$

(C) $d_1 = d_2$

(D) It depends entirely on the ratio of their masses

**Q16.** During the process of radioactive $\beta^-$ (beta minus) decay, what change occurs inside the nucleus?

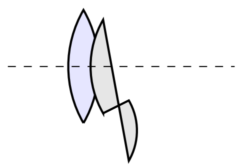
(A) A proton converts into a neutron

(B) A neutron converts into a proton

(C) An alpha particle is ejected

(D) The mass number decreases by 4

**Q17.** A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 25 cm. What is the net power of this lens combination?



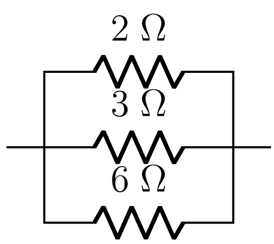
(A) $+9$ D

(B) $-1$ D

(C) $+1$ D

(D) $+4.5$ D

**Q18.** Three resistors of values $2\ \Omega$, $3\ \Omega$, and $6\ \Omega$ are connected in parallel. What is the equivalent resistance of this network?




(A) $11\ \Omega$

(B) $1\ \Omega$

(C) $1.5\ \Omega$

(D) $0.5\ \Omega$

**Q19.** A body starts from rest and moves with a uniform acceleration of $4$ m/s$^2$. What is the distance covered by the body during the $5^{\text{th}}$ second of its motion?

(A) $50$ m

(B) $18$ m

(C) $25$ m

(D) $20$ m

**Q20.** How much heat energy is required to raise the temperature of $2$ kg of water from $20°$C to $60°$C? (Take the specific heat capacity of water as $4200$ J/(kg $\cdot°$ C))

(A) $336,000$ J

(B) $168,000$ J

(C) $84,000$ J

(D) $504,000$ J

**Q21.** A girl stands in front of a large echoing wall and claps her hands. She hears the echo after $0.4$ s. If the speed of sound in air is $340$ m/s, how far is she standing from the wall?

(A) $136$ m

(B) $68$ m

(C) $272$ m

(D) $34$ m

**Q22.** A constant force acts on an object of mass $5$ kg for a duration of $2$ s. It increases the object's velocity from $3$ m/s to $7$ m/s. Find the magnitude of the applied force.

(A) 10 N

(B) 5 N

(C) 20 N

(D) 15 N

**Q23.** Which of the following phenomena is primarily responsible for the brilliant sparkling of a diamond?

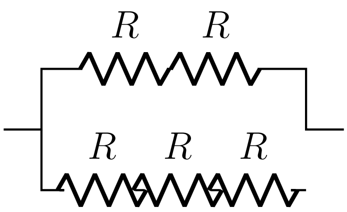
(A) Total Internal Reflection

(B) Total Interference

(C) Diffuse Reflection

(D) Atmospheric Refraction

**Q24.** In an electric circuit, five identical resistors each of value $R$ are arranged such that two are in series, and this pair is connected in parallel with the remaining three resistors connected in series. What is the total effective resistance of this circuit?




(A) $\frac{5}{6}R$

(B) $\frac{6}{5}R$

(C) $5R$

(D) $\frac{2}{3}R$

**Q25.** Equal masses of two different liquids $A$ and $B$ are heated using identical heat sources. If the temperature of liquid $A$ rises twice as fast as that of liquid $B$, what is the ratio of their specific heat capacities $(C_A : C_B)$?

(A) $2:1$

(B) $1:2$

(C) $1 : 4$

(D) $4 : 1$

# Detailed Solutions

## Q1.

### Solution

**Concept:**
The total distance traveled by an object is the actual length of the path covered during its entire journey, which is a scalar quantity. The magnitude of displacement is the shortest straight-line distance between the initial position and the final position, which is a vector quantity. For a circular path, completing one full revolution covers a distance equal to the circumference $2\pi R$, while the displacement depends purely on the final coordinates relative to the start point.

**Solution:**
Step 1: Calculate the total distance covered in two and a half revolutions.
One complete revolution equals the circumference of the circle, which is given by $2\pi R$.
Therefore, the distance covered in $2.5$ revolutions is:

$$\text{Distance} = 2.5 \times 2\pi R = 5\pi R$$

Step 2: Determine the final position of the particle to find the displacement.
After the first full revolution, the particle returns to its starting point.
After the second full revolution, it is again at the starting point.
The remaining half revolution ($0.5$ revolution) brings the particle to a point diametrically opposite to its initial starting point.

Step 3: Calculate the magnitude of the displacement.
Since the final position is exactly on the opposite side of the circular path along the diameter, the shortest straight-line distance from the start point to the end point is equal to the diameter of the circle.

$$\text{Magnitude of Displacement} = 2R$$

Step 4: Find the ratio of the total distance covered to the magnitude of its displacement.

$$\text{Ratio} = \frac{\text{Total Distance}}{\text{Magnitude of Displacement}} = \frac{5\pi R}{2R} = \frac{5\pi}{2}$$

**Final Answer:** $\boxed{\frac{5\pi}{2}}$

**Answer: (B)** Go Back to Question 1

# Q2.

## Solution

**Concept:**

The electrical resistance of an appliance is a constant property determined by its design and construction, assuming the temperature remains constant. The power rating ($P$) of an electrical appliance is related to its rated operational voltage ($V$) and its internal resistance ($R$) by Joule's Law of heating, expressed as $P = \frac{V^2}{R}$. When the appliance is operated at a different voltage, its resistance remains unchanged, and the new power consumption can be determined using the new operational voltage.

**Solution:**

Step 1: Extract the rated parameters from the given problem statement.

Rated Voltage ($V_1$) = 220 V

Rated Power ($P_1$) = 100 W

Applied Voltage ($V_2$) = 110 V

Step 2: Calculate the internal operational resistance ($R$) of the electrical appliance using the rated values.

From the formula $P_1 = \frac{V_1^2}{R}$, we can rearrange the terms to solve explicitly for $R$:

$$R = \frac{V_1^2}{P_1} = \frac{220 \times 220}{100} = \frac{48400}{100} = 484\ \Omega$$

Step 3: Calculate the new actual power consumption ($P_2$) when operating at the lower applied voltage ($V_2$).

Using the calculated resistance value and the new voltage, we apply the power formula again:

$$P_2 = \frac{V_2^2}{R} = \frac{110 \times 110}{484} = \frac{12100}{484} = 25\ \text{W}$$

Step 4: Alternatively, use a proportional method to verify the result.

Since resistance $R$ is constant, power is directly proportional to the square of the voltage ($P \propto V^2$).

$$\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^2 = \left(\frac{110}{220}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

$$P_2 = \frac{P_1}{4} = \frac{100}{4} = 25\ \text{W}$$

**Final Answer:** 25 W

**Answer: (B)** Go Back to Question 2

## Q3.

### Solution

**Concept:**
The refractive index of a medium with respect to another medium is a relative measure of how much light slows down or changes direction when passing across their boundary interface. According to the principles of optics, the relative refractive index of medium 2 with respect to medium 1 is denoted as ${}^{1}\mu_2$ (or $n_{21}$) and is defined as the ratio of the absolute refractive index of the second medium to the absolute refractive index of the first medium.

**Solution:**
Step 1: Identify the absolute refractive indices of the two given media from the problem text.
Let medium 1 be water: $\mu_1 = \frac{4}{3}$
Let medium 2 be glass: $\mu_2 = \frac{3}{2}$

Step 2: Apply the fundamental formula for the relative refractive index of glass with respect to water.
The relative refractive index is mathematically structured as:

$$\text{Refractive index of glass with respect to water} = {}^{\text{water}}\mu_{\text{glass}} = \frac{\mu_{\text{glass}}}{\mu_{\text{water}}}$$

Step 3: Substitute the fractional values into the relative index equation.

$${}^{\text{water}}\mu_{\text{glass}} = \frac{\frac{3}{2}}{\frac{4}{3}}$$

Step 4: Simplify the complex fraction by multiplying the numerator by the reciprocal of the denominator.

$${}^{\text{water}}\mu_{\text{glass}} = \frac{3}{2} \times \frac{3}{4} = \frac{3 \times 3}{2 \times 4} = \frac{9}{8}$$

This indicates that light travels slower in glass than in water by this specific proportional factor.

**Final Answer:** $\boxed{\frac{9}{8}}$

**Answer: (B)** Go Back to Question 3

# Q4.

## Solution

**Concept:**

A hydraulic lift operates directly on the basis of Pascal's Principle, which states that any pressure change applied to an enclosed, incompressible fluid is transmitted undiminished throughout the fluid to all portions of the fluid and the walls of its container. Since pressure is defined as force per unit area ($P = \frac{F}{A}$), a small force applied over a small area creates an identical pressure change that can generate a much larger output force when acting over a significantly larger cross-sectional area.

**Solution:**

Step 1: State the given parameters for the small and large pistons.

Area of the small piston $(A_1) = 0.02 \text{ m}^2$

Force applied to the small piston $(F_1) = 50 \text{ N}$

Area of the large piston $(A_2) = 0.8 \text{ m}^2$

Maximum weight (force) on the large piston $= F_2$

Step 2: Set up the mathematical equation balancing the fluid pressures according to Pascal's law.

$$P_1 = P_2 \implies \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Step 3: Rearrange the equation to isolate the unknown variable $F_2$, representing the maximum lift capacity.

$$F_2 = F_1 \times \left(\frac{A_2}{A_1}\right)$$

Step 4: Substitute the given numerical values into the rearranged equation and solve.

$$F_2 = 50 \times \left(\frac{0.8}{0.02}\right)$$

Simplify the area fraction by clearing the decimals:

$$\frac{0.8}{0.02} = \frac{80}{2} = 40$$

Now, compute the product:

$$F_2 = 50 \times 40 = 2000 \text{ N}$$

Thus, the mechanical advantage allows a small force to lift a massive weight of 2000 N.

**Final Answer:** 2000 N

**Answer: (A)** Go Back to Question 4

## Q5.

### Solution

**Concept:**
Newton's Second Law of Motion states that the net force acting on an object is directly equal to the rate of change of its linear momentum over time. Alternatively, this can be solved using kinematics to find the uniform retarding acceleration and then multiplying it by the mass of the object ($F = ma$). The negative sign in acceleration denotes retardation, but the question asks for the magnitude, which represents absolute force value.

**Solution:**
Step 1: Identify and convert all initial quantities into Standard International (SI) units.
Mass of the bullet $(m)$ = 20 g = $\frac{20}{1000}$ kg = 0.02 kg
Initial velocity $(u)$ = 150 m/s
Final velocity $(v)$ = 0 m/s (since it comes to rest)
Time interval $(\Delta t)$ = 0.03 s

Step 2: Use the first equation of motion to calculate the deceleration or retardation $(a)$.

$$v = u + at \implies 0 = 150 + a(0.03)$$
$$a = -\frac{150}{0.03} = -\frac{15000}{3} = -5000 \text{ m/s}^2$$

The negative sign signifies a retarding acceleration of magnitude $5000 \text{ m/s}^2$.

Step 3: Apply Newton's second law to find the magnitude of the average retarding force $(F)$.

$$F = m \times |a|$$
$$F = 0.02 \times 5000 = \frac{2}{100} \times 5000 = 2 \times 50 = 100 \text{ N}$$

The structural resistance of the sandbag exerts an average backward force of $100$ N to stop the bullet.

**Final Answer:** 100 N

**Answer: (A)** Go Back to Question 5

# Q6.

## Solution

**Concept:**

Radioactive decay follows a statistical first-order process where the amount of remaining active material decreases exponentially over time. The half-life ($T_{1/2}$) is defined as the time period required for a radioactive sample to decay to exactly half of its initial mass. The quantity remaining undecayed after a total elapsed time $t$ can be calculated using the relation $N = N_0 \left(\frac{1}{2}\right)^n$, where $n$ represents the total number of elapsed half-lives.

**Solution:**

Step 1: Determine the key parameters given in the problem statement.
Initial mass ($N_0$) = $100$ g
Half-life ($T_{1/2}$) = $4$ hours
Total decay time ($t$) = $12$ hours

Step 2: Calculate the number of half-lives ($n$) that occur within the total duration.

$$n = \frac{\text{Total time } (t)}{\text{Half-life } (T_{1/2})} = \frac{12}{4} = 3$$

This means the sample undergoes three consecutive halving cycles.

Step 3: Calculate the remaining mass ($N$) step-by-step or by using the decay formula.
Using the formula:

$$N = N_0 \times \left(\frac{1}{2}\right)^n = 100 \times \left(\frac{1}{2}\right)^3$$

$$N = 100 \times \frac{1}{8} = 12.5 \text{ g}$$

Alternatively, step-by-step tracking:
- Initially: $100$ g
- After 4 hours (1st half-life): $50$ g
- After 8 hours (2nd half-life): $25$ g
- After 12 hours (3rd half-life): $12.5$ g

**Final Answer:** $\boxed{12.5 \text{ g}}$

**Answer: (C)** Go Back to Question 6

# Q7.

## Solution

**Concept:**
Spherical mirrors form images according to the mirror formula, which correlates the focal length ($f$), the object distance ($u$), and the image distance ($v$). The Cartesian sign convention must be applied strictly: distances measured in the direction of incident light are positive, while distances measured against incident light are negative. For a concave mirror, the real focus lies in front of the mirror, making its focal length negative. Real images are formed on a screen placed in front of the mirror, meaning the screen position corresponds to the image distance.

**Solution:**
Step 1: Apply the Cartesian sign convention to the given numerical data.
Focal length of the concave mirror ($f$) = $-10$ cm
Object distance ($u$) = $-15$ cm
Image distance / Screen position = $v$

Step 2: State the standard spherical mirror formula.

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

Step 3: Rearrange the terms to express the equation in terms of the unknown image variable $\frac{1}{v}$.

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

Step 4: Substitute the signed numerical values and perform fractional subtraction.

$$\frac{1}{v} = \frac{1}{-10} - \frac{1}{-15} = -\frac{1}{10} + \frac{1}{15}$$

Find a common denominator for 10 and 15, which is 30:

$$\frac{1}{v} = \frac{-3+2}{30} = -\frac{1}{30}$$

Taking the reciprocal yields:

$$v = -30 \text{ cm}$$

The negative sign indicates that the image is formed at a distance of 30 cm in front of the mirror, meaning a physical screen must be placed exactly at that distance to capture the real, inverted image.

**Final Answer:** $-30$ cm

**Answer: (A)** Go Back to Question 7

# Q8.

## Solution

**Concept:**
According to the Law of Conservation of Mechanical Energy, the total mechanical energy (the sum of potential energy and kinetic energy) of an isolated system remains completely constant in the absence of dissipative structural forces like air resistance or friction. When an object is dropped from a rest position at a height, its initial kinetic energy is zero, and it possesses maximum gravitational potential energy. As it falls, potential energy is converted continuously into kinetic energy.

**Solution:**
Step 1: Calculate the total initial mechanical energy at the top of the tower.
At height $H = 40$ m, the velocity is zero, so initial kinetic energy ($K_{\text{initial}}$) = 0.
Initial potential energy is:

$$U_{\text{initial}} = m \times g \times H$$

$$U_{\text{initial}} = 2 \times 10 \times 40 = 800 \text{ J}$$

Total Mechanical Energy = $U_{\text{initial}} + K_{\text{initial}} = 800 + 0 = 800$ J.

Step 2: Analyze the energy state at the halfway mark.
The halfway height is given by:

$$h = \frac{H}{2} = \frac{40}{2} = 20 \text{ m}$$

Step 3: Calculate the gravitational potential energy ($U_{\text{half}}$) remaining at this halfway point.

$$U_{\text{half}} = m \times g \times h = 2 \times 10 \times 20 = 400 \text{ J}$$

Step 4: Apply the conservation of energy principle to find the kinetic energy ($K_{\text{half}}$).

$$\text{Total Mechanical Energy} = U_{\text{half}} + K_{\text{half}}$$

$$800 = 400 + K_{\text{half}}$$

$$K_{\text{half}} = 800 - 400 = 400 \text{ J}$$

Thus, exactly half of the potential energy has transformed into kinetic energy at the mid-point.

**Final Answer:** 400 J

**Answer: (B)** Go Back to Question 8

## Q9.

### Solution

**Concept:**

The speed ($v$) of a wave through any uniform medium is a function of its physical properties and is linked to its frequency ($f$) and wavelength ($\lambda$) by the fundamental wave equation $v = f\lambda$. Once the propagation velocity is established, the time required to cover a specified straight-line distance can be found using the classical kinematic definition of uniform speed, where time $= \frac{\text{distance}}{\text{speed}}$.

**Solution:**

Step 1: Convert all given metrics into standard base SI units.

Frequency ($f$) $= 2 \text{ kHz} = 2 \times 1000 \text{ Hz} = 2000 \text{ Hz}$

Wavelength ($\lambda$) $= 35 \text{ cm} = \frac{35}{100} \text{ m} = 0.35 \text{ m}$

Distance to travel ($d$) $= 1.4 \text{ km} = 1.4 \times 1000 \text{ m} = 1400 \text{ m}$

Step 2: Compute the velocity ($v$) of the sound wave.

Using the wave equation:

$$v = f \times \lambda$$

$$v = 2000 \times 0.35 = 200 \times 3.5 = 700 \text{ m/s}$$

Step 3: Calculate the total time ($t$) required to travel the distance of $1400$ m.

Using the constant velocity relationship:

$$t = \frac{d}{v}$$

$$t = \frac{1400}{700} = 2 \text{ s}$$

The sound wave takes exactly two seconds to cross a distance of $1.4$ km.

**Final Answer:** $\boxed{2 \text{ s}}$

**Answer: (A)** Go Back to Question 9

## Q10.

### Solution

**Concept:**

The resistance of a regular conductor depends on its physical dimensions according to $R = \rho\frac{l}{A}$, where $\rho$ represents the constant material resistivity, $l$ is length, and $A$ is the cross-sectional area. When a metallic wire is stretched uniformly without losing mass, its total physical volume remains constant. Therefore, an increase in length must be accompanied by a proportional decrease in its cross-sectional area.

**Solution:**

Step 1: Set up the volume conservation equation.
Let the initial length be $l_1$ and area be $A_1$. The initial resistance is $R_1 = \rho\frac{l_1}{A_1} = R$.
The new length after stretching is $l_2 = 2l_1$.
Since total volume ($V =$ length $\times$ area) is constant:

$$V = l_1 \times A_1 = l_2 \times A_2$$

$$l_1 \times A_1 = (2l_1) \times A_2 \implies A_2 = \frac{A_1}{2}$$

The cross-sectional area is reduced to half its initial size.

Step 2: Express the new resistance ($R_2$) in terms of modified parameters.

$$R_2 = \rho\frac{l_2}{A_2}$$

Step 3: Substitute $l_2$ and $A_2$ expressions into the new resistance equation.

$$R_2 = \rho\frac{2l_1}{\left(\frac{A_1}{2}\right)} = \rho\frac{2 \times 2 \times l_1}{A_1} = 4\left(\rho\frac{l_1}{A_1}\right)$$

Step 4: Substitute the original resistance $R$ to determine the scale factor.

$$R_2 = 4R$$

Stretching a wire to double its length results in a four-fold increase in electrical resistance.

**Final Answer:** $\boxed{4R}$

**Answer: (B)** Go Back to Question 10

## Q11.

### Solution

**Concept:**
Temperature scales use different mathematical reference intervals for freezing and boiling points, establishing distinct linear equations for thermal measurement. The mathematical relationship linking the Celsius scale (°C) and the Fahrenheit scale (°F) is derived from their respective operational ranges, given by the linear conversion equation: $\frac{C}{5} = \frac{F-32}{9}$. To find the specific point where both scales display identical values, we set their variables equal to a common algebraic value.

**Solution:**
Step 1: Assume a common temperature variable $x$ where both values are numerically identical.

$$C = F = x$$

Step 2: Substitute $x$ for both temperature variables in the conversion formula.

$$\frac{x}{5} = \frac{x-32}{9}$$

Step 3: Cross-multiply to solve the linear algebraic equation.

$$9 \times x = 5 \times (x - 32)$$

$$9x = 5x - 160$$

Step 4: Isolate the variable $x$ on one side of the equation.

$$9x - 5x = -160$$

$$4x = -160$$

$$x = -\frac{160}{4} = -40$$

Therefore, a reading of $-40°$ represents the exact same physical thermal state on both scales.

**Final Answer:** $\boxed{-40°}$

**Answer: (B)** **Go Back to Question 11**

## Q12.

### Solution

**Concept:**
The number of images formed by a combination of two plane mirrors depends on the angle $\theta$ between them. The formula for the number of images formed is generally given by $n = \frac{360^\circ}{\theta} - 1$ when $\frac{360^\circ}{\theta}$ is an even integer. When the two plane mirrors are placed perfectly parallel to each other, facing inwards, the angle $\theta$ between them is exactly $0^\circ$.

**Solution:**
Step 1: Identify the angular separation between the two mirrors.
For parallel planes, $\theta = 0^\circ$.

Step 2: Substitute the angle value into the image allocation relationship.

$$n = \frac{360^\circ}{0^\circ} - 1$$

Step 3: Evaluate the mathematical limit as the divisor approaches zero.
Division of any finite positive value by zero approaches infinity ($\infty$). Each image formed in one mirror acts as a virtual object for the opposing mirror, generating a continuous, unending sequence of reflections.
Therefore, an infinite number of images are theoretically formed, fading in intensity due to partial absorption of light during each reflection.

**Final Answer:** Infinite

**Answer: (D)** Go Back to Question 12

## Q13.

### Solution

**Concept:**

Power is physically defined as the rate at which work is performed or energy is converted over a given duration of time. The average power output ($P$) is calculated as the ratio of total work done ($W$) to the total time interval ($t$) taken to complete that work, expressed by the equation $P = \frac{W}{t}$. The standard unit of power is the Watt (W), which corresponds directly to one Joule per second (J/s).

**Solution:**

Step 1: Identify and convert the given physical metrics into uniform SI quantities.
Work done ($W$) = $1800$ J
Time period ($t$) = $1$ minute $= 60$ seconds

Step 2: Apply the fundamental power formulation.

$$P = \frac{W}{t}$$

Step 3: Substitute the values into the equation and compute the division.

$$P = \frac{1800}{60}$$

Cancel the zeros in the numerator and denominator:

$$P = \frac{180}{6} = 30 \text{ W}$$

The system delivers energy at a steady rate of $30$ Joules per second.

**Final Answer:** $\boxed{30 \text{ W}}$

**Answer: (C)** Go Back to Question 13

## Q14.

### Solution

**Concept:**
Electrical power ($P$) consumed by an appliance can be calculated from its operational parameters using $P = V \times I$, where $V$ is the potential difference and $I$ is the current. Total electrical energy consumed over a period is the product of power and the total time of operation ($E = P \times t$). Commercial electrical consumption is measured in kilowatt-hours (kWh), where 1 kWh represents 1000 Watts of power sustained continuously for an operational period of one hour.

**Solution:**
Step 1: Calculate the power rating of the electric iron in Watts.
Given Current ($I$) = 5 A
Given Voltage ($V$) = 220 V

$$P = V \times I = 220 \times 5 = 1100 \text{ W}$$

Step 2: Convert the calculated power rating from Watts to Kilowatts (kW).

$$P_{\text{kW}} = \frac{1100}{1000} = 1.1 \text{ kW}$$

Step 3: Calculate the total operational hours over the specified duration.
Daily operational use = 2 hours/day
Total number of days = 30 days

$$\text{Total time } (t) = 2 \times 30 = 60 \text{ hours}$$

Step 4: Calculate the total electrical energy consumed in commercial units (kWh).

$$E = P_{\text{kW}} \times t = 1.1 \text{ kW} \times 60 \text{ hours} = 66 \text{ kWh}$$

The appliance consumes 66 units of electricity over the 30 days.

**Final Answer:** $\boxed{66 \text{ kWh}}$

**Answer: (A)** **Go Back to Question 14**

## Q15.

### Solution

**Concept:**
According to the Work-Energy Theorem, the net work done by all forces acting on an object is directly equal to the change in its kinetic energy ($\Delta K$). When a moving vehicle is brought to rest by braking, the work done by the retarding braking force matches its initial kinetic energy. The work done by a constant force is defined as the product of the force and the displacement in the direction of the force ($W = F \times d$).

**Solution:**
Step 1: Set up the structural equations based on the Work-Energy Theorem.
Let the initial kinetic energy of both the truck and the car be $K$, since they are specified as equal ($K_1 = K_2 = K$).
Let the constant braking force applied to both vehicles be $F$.

Step 2: Formulate the equations for the stopping distance of both vehicles.
For the truck:

$$W_1 = \Delta K \implies F \times d_1 = K \implies d_1 = \frac{K}{F}$$

For the car:

$$W_2 = \Delta K \implies F \times d_2 = K \implies d_2 = \frac{K}{F}$$

Step 3: Compare the derived expressions for $d_1$ and $d_2$.
Since the kinetic energy $K$ is identical for both vehicles and the retarding force $F$ is also identical, their stopping distances must be exactly equal.

$$d_1 = d_2$$

The stopping distance is independent of the mass of the vehicles when both initial kinetic energy and braking forces are identical.

**Final Answer:** $\boxed{d_1 = d_2}$

**Answer: (C)** Go Back to Question 15

## Q16.

### Solution

**Concept:**

Radioactive $\beta^-$ (beta minus) decay occurs in unstable, neutron-rich atomic nuclei that seek a more stable configurations. During this weak nuclear interaction, a neutron inside the parent nucleus spontaneously transforms into a proton, an electron (emitted as a $\beta^-$ particle), and an electron antineutrino. This transformation alters the atomic number while preserving the total number of nucleons.

**Solution:**

Step 1: Analyze the fundamental nuclear reaction during a beta-minus decay process.
The decay equation at the nucleon level is written as:

$$n \to p + e^- + \bar{\nu}_e$$

Where $n$ represents a neutron, $p$ is a proton, $e^-$ is the emitted beta electron, and $\bar{\nu}_e$ is the antineutrino.

Step 2: Evaluate the impact on the atomic mass number ($A$).
Since one neutron is lost but one proton is gained, the total number of nucleons ($Z + N$) remains constant. Thus, $\Delta A = 0$.

Step 3: Evaluate the impact on the atomic number ($Z$).
The formation of an additional proton increases the net positive charge of the nucleus by exactly one unit ($Z \to Z + 1$).

Step 4: Match the structural change with the options provided.
The underlying event is that a neutron inside the nucleus converts directly into a proton.

**Final Answer:** A neutron converts into a proton

**Answer: (B)** Go Back to Question 16

## Q17.

### Solution

**Concept:**

The power ($P$) of a spherical lens is defined as the reciprocal of its focal length measured in meters ($P = \frac{1}{f}$). According to optical principles, a convex (converging) lens has a positive focal length, whereas a concave (diverging) lens has a negative focal length. When two thin lenses are placed in close contact, the net power of the combination is equal to the algebraic sum of the individual powers: $P_{\text{net}} = P_1 + P_2$.

**Solution:**

Step 1: Convert individual focal lengths into standard units and assign correct signs.
Focal length of the convex lens ($f_1$) $= +20$ cm $= +0.2$ m
Focal length of the concave lens ($f_2$) $= -25$ cm $= -0.25$ m

Step 2: Calculate the individual power values in Diopters (D).

$$P_1 = \frac{1}{f_1} = \frac{1}{+0.2} = +5 \text{ D}$$

$$P_2 = \frac{1}{f_2} = \frac{1}{-0.25} = -4 \text{ D}$$

Step 3: Calculate the net power of the lens combination.

$$P_{\text{net}} = P_1 + P_2$$

$$P_{\text{net}} = (+5 \text{ D}) + (-4 \text{ D}) = +1 \text{ D}$$

The lens combination behaves as a weak converging lens with a net power of $+1$ Diopter.

**Final Answer:** $\boxed{+1 \text{ D}}$

**Answer: (C)** **Go Back to Question 17**

## Q18.

### Solution

**Concept:**

When multiple electrical resistors are connected in a parallel configuration, the potential difference across each resistor remains identical, while the total current is divided among the branches. The reciprocal of the equivalent resistance ($R_{eq}$) of a parallel network is equal to the sum of the reciprocals of the individual resistances: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.

**Solution:**

Step 1: State the given resistance values.

$R_1 = 2\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 6\ \Omega$

Step 2: Set up the parallel equivalent resistance equation.

$$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$$

Step 3: Find a common denominator to add the fractions.

The least common multiple (LCM) of 2, 3, and 6 is 6.

$$\frac{1}{R_{eq}} = \frac{3}{6} + \frac{2}{6} + \frac{1}{6}$$

$$\frac{1}{R_{eq}} = \frac{3+2+1}{6} = \frac{6}{6} = 1\ \Omega^{-1}$$

Step 4: Take the reciprocal to find the equivalent resistance value.

$$R_{eq} = 1\ \Omega$$

The net resistance of the parallel combination is smaller than the smallest individual resistor in the network.

**Final Answer:** $1\ \Omega$

**Answer: (B)** Go Back to Question 18

## Q19.

### Solution

**Concept:**
The distance covered by a uniformly accelerating body during a specific $n^{\text{th}}$ second of its motion is derived from kinematic principles. It represents the difference between the total displacement after $n$ seconds and the total displacement after $(n-1)$ seconds $(S_n - S_{n-1})$. This relation is expressed by the formula: $S_{n^{\text{th}}} = u + \frac{a}{2}(2n-1)$, where $u$ is the initial velocity, $a$ is the constant acceleration, and $n$ is the specific second.

**Solution:**
Step 1: Extract the given motion parameters from the problem statement.
Initial velocity $(u) = 0$ m/s (since it starts from rest)
Uniform acceleration $(a) = 4$ m/s$^2$
Target time interval $(n) = 5$ (representing the $5^{\text{th}}$ second)

Step 2: Apply the values to the $n^{\text{th}}$-second distance formula.

$$S_{5^{\text{th}}} = u + \frac{a}{2}(2n-1)$$

$$S_{5^{\text{th}}} = 0 + \frac{4}{2}\,(2(5)-1)$$

Step 3: Simplify the expression inside the parentheses and compute the result.

$$S_{5^{\text{th}}} = 2 \times (10-1)$$

$$S_{5^{\text{th}}} = 2 \times 9 = 18 \text{ m}$$

The body covers exactly $18$ meters during the interval between $t = 4$ s and $t = 5$ s.

**Final Answer:** 18 m

**Answer: (B)** Go Back to Question 19

# Q20.

## Solution

**Concept:**

The amount of heat energy ($Q$) required to change the temperature of a given mass of a substance without a phase change depends on its mass ($m$), its specific heat capacity ($c$), and the total temperature difference ($\Delta T$). The relationship is defined by the thermal equation $Q = mc\Delta T$. Specific heat capacity represents the energy needed to raise the temperature of 1 kg of a substance by 1°C.

**Solution:**

Step 1: Identify the given thermal parameters.
Mass of water ($m$) = 2 kg
Specific heat capacity ($c$) = 4200 J/(kg ·° C)
Initial temperature ($T_1$) = 20°C
Final temperature ($T_2$) = 60°C

Step 2: Calculate the net change in temperature ($\Delta T$).

$$\Delta T = T_2 - T_1 = 60°\text{C} - 20°\text{C} = 40°\text{C}$$

Step 3: Substitute the values into the formula to calculate the heat energy.

$$Q = m \times c \times \Delta T$$

$$Q = 2 \times 4200 \times 40$$

Step 4: Compute the product systematically.

$$Q = 8400 \times 40 = 336,000 \text{ J}$$

Thus, $336,000$ Joules (or $336$ kJ) of heat energy must be absorbed by the water.

**Final Answer:** $\boxed{336,000 \text{ J}}$

**Answer: (A)** Go Back to Question 20

# Q21.

## Solution

**Concept:**
An echo is formed when a sound wave reflects off a distant surface and returns to the source. The total distance traveled by the sound wave from the moment it is produced to the moment it is heard as an echo is equal to twice the distance ($d$) between the source and the reflecting surface ($2d$). Using the definition of constant velocity, the total distance traveled is the product of the speed of sound ($v$) and the total time elapsed ($t$).

**Solution:**
Step 1: State the given parameters.
Speed of sound in air ($v$) = $340$ m/s
Total echo time delay ($t$) = $0.4$ s

Step 2: Set up the kinematic relation for the sound wave path.

$$\text{Total Distance Traveled by Sound} = \text{Speed} \times \text{Time}$$

$$2d = v \times t$$

Where $d$ is the straight-line distance from the girl to the wall.

Step 3: Rearrange the equation to solve for the distance $d$.

$$d = \frac{v \times t}{2}$$

Step 4: Substitute the numerical values into the equation.

$$d = \frac{340 \times 0.4}{2}$$

$$d = 340 \times 0.2 = 68 \text{ m}$$

The girl is standing at a distance of $68$ meters from the echoing wall.

**Final Answer:** $\boxed{68 \text{ m}}$

**Answer: (B)** Go Back to Question 21

## Q22.

### Solution

**Concept:**

According to Newton's Second Law of Motion, a constant force applied to an object causes a uniform acceleration, defined as the rate of change of its velocity. The applied force can be determined using $F = ma$, where acceleration $a$ is calculated from the initial velocity $(u)$, final velocity $(v)$, and time interval $(t)$ using $a = \frac{v-u}{t}$. Alternatively, force can be expressed as the rate of change of momentum: $F = \frac{m(v-u)}{t}$.

**Solution:**

Step 1: Identify the given dynamic variables.
Mass of the object $(m)$ = 5 kg
Initial velocity $(u)$ = 3 m/s
Final velocity $(v)$ = 7 m/s
Time duration $(t)$ = 2 s

Step 2: Calculate the uniform acceleration $(a)$ of the object.

$$a = \frac{v-u}{t} = \frac{7-3}{2} = \frac{4}{2} = 2 \text{ m/s}^2$$

Step 3: Apply Newton's second law to find the magnitude of the force $(F)$.

$$F = m \times a$$

$$F = 5 \times 2 = 10 \text{ N}$$

A constant force of 10 Newtons is required to produce this change in velocity over the 2-second interval.

**Final Answer:** $\boxed{10 \text{ N}}$

**Answer: (A)** **Go Back to Question 22**

## Q23.

### Solution

**Concept:**
The sparkling of a diamond is an optical phenomenon that depends on its high refractive index and geometric cut. Diamond has a high refractive index ($\approx 2.42$), which results in a small critical angle ($\approx 24.4^\circ$). When raw diamonds are skillfully cut with precise angular faces, light entering the gemstone strikes the internal walls at angles greater than this critical angle, causing repeated internal reflections before exiting.

**Solution:**
Step 1: Define Total Internal Reflection (TIR).
Total Internal Reflection occurs when a ray of light traveling through an optically denser medium strikes the boundary of a rarer medium at an angle of incidence greater than the critical angle, causing the light to reflect entirely back into the denser medium.

Step 2: Analyze why a diamond sparkles based on this phenomenon.
Because the critical angle for a diamond-to-air interface is small ($24.4^\circ$), light entering the diamond is highly likely to experience multiple total internal reflections before finding a face that allows it to exit. This trapping and concentration of light causes the gemstone to sparkle vividly when viewed from specific directions.

Step 3: Evaluate the alternatives.
Interference, diffuse reflection, and atmospheric refraction do not account for the internal trapping of light inside a gemstone. Therefore, Total Internal Reflection is the primary mechanism.

**Final Answer:** Total Internal Reflection

**Answer: (A)** Go Back to Question 23

## Q24.

### Solution

**Concept:**
To find the total equivalent resistance of a complex circuit network, the circuit is simplified by identifying and calculating series and parallel combinations in stages. For resistors in series, the resistances add up directly ($R_{series} = R_1 + R_2 + \ldots$). For two parallel branches, the combined resistance is calculated using the product-over-sum rule: $R_{parallel} = \frac{R_{branch1} \times R_{branch2}}{R_{branch1} + R_{branch2}}$.

**Solution:**
Step 1: Analyze the first branch of the circuit.
The first branch consists of two identical resistors of value $R$ connected in series.

$$\text{Resistance of Branch 1 } (R_1) = R + R = 2R$$

Step 2: Analyze the second branch of the circuit.
The remaining three identical resistors of value $R$ are connected in series in a parallel branch.

$$\text{Resistance of Branch 2 } (R_2) = R + R + R = 3R$$

Step 3: Calculate the net effective resistance ($R_{eq}$) of the two parallel branches.
The branch resistances $R_1 = 2R$ and $R_2 = 3R$ are in parallel. Applying the parallel formula:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2R} + \frac{1}{3R}$$

Find a common denominator, which is $6R$:

$$\frac{1}{R_{eq}} = \frac{3+2}{6R} = \frac{5}{6R}$$

Step 4: Take the reciprocal to find the total equivalent resistance.

$$R_{eq} = \frac{6}{5}R$$

**Final Answer:** $\boxed{\frac{6}{5}R}$

**Answer: (B)** **Go Back to Question 24**

## Q25.

### Solution

**Concept:**
The heat energy absorbed by a substance is related to its specific heat capacity by the equation $Q = mc\Delta T$. The rate of temperature rise can be expressed as $\frac{\Delta T}{t}$, representing how quickly the temperature changes when heat is supplied at a constant rate $(\frac{Q}{t})$. For identical heat sources, the rate of heat transfer $(\frac{Q}{t})$ is equal for both substances.

**Solution:**
Step 1: Express the heat supply equation for both liquids.
Let the mass of both liquids be $m$, as they are specified as equal ($m_A = m_B = m$).
Let the constant heat supply rate from the identical sources be $P = \frac{Q}{t}$.
From $Q = mc\Delta T$, dividing by time $t$ gives:

$$P = m \cdot C \cdot \left(\frac{\Delta T}{t}\right)$$

Step 2: Set up the equations for liquids $A$ and $B$.
For liquid $A$: $P = m \cdot C_A \cdot \left(\frac{\Delta T_A}{t}\right)$
For liquid $B$: $P = m \cdot C_B \cdot \left(\frac{\Delta T_B}{t}\right)$

Step 3: Use the given relationship between their rates of temperature rise.
The problem states that the temperature of liquid $A$ rises twice as fast as that of liquid $B$:

$$\left(\frac{\Delta T_A}{t}\right) = 2 \times \left(\frac{\Delta T_B}{t}\right)$$

Step 4: Equate the two power expressions since the heat sources are identical.

$$m \cdot C_A \cdot \left(\frac{\Delta T_A}{t}\right) = m \cdot C_B \cdot \left(\frac{\Delta T_B}{t}\right)$$

Cancel the common mass variable $m$:

$$C_A \cdot 2\left(\frac{\Delta T_B}{t}\right) = C_B \cdot \left(\frac{\Delta T_B}{t}\right)$$

Cancel the rate of temperature rise of $B$ from both sides:

$$2 \cdot C_A = C_B \implies \frac{C_A}{C_B} = \frac{1}{2}$$

Therefore, the ratio of their specific heat capacities is $1 : 2$.

**Final Answer:** $\boxed{1 : 2}$

**Answer: (B)** Go Back to Question 25

## Answer Key

| Q | Ans | Q | Ans | Q | Ans | Q | Ans | Q | Ans |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | B | 3 | B | 4 | A | 5 | A |
| 6 | C | 7 | A | 8 | B | 9 | A | 10 | B |
| 11 | B | 12 | D | 13 | C | 14 | A | 15 | C |
| 16 | B | 17 | C | 18 | B | 19 | B | 20 | A |
| 21 | B | 22 | A | 23 | A | 24 | B | 25 | B |