CIE A-Level Physics (9702/12) - Paper 1 Solutions

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Multiple Choice Questions

1. Which row correctly identifies scalar and vector quantities? [1]

	scalar quantities	**vector quantities**
A	energy and work	momentum and power
B	energy and momentum	force and power
C	energy and power	force and momentum
D	momentum and power	force and velocity

Solution & Reasoning

To distinguish between scalars and vectors, recall that a scalar possesses only magnitude, whereas a vector requires both magnitude and direction to be fully defined.

- *Energy, work, and power* do not have a spatial direction. They are scalar quantities.
- *Force, momentum, and velocity* inherently act in specific directions. They are vector quantities.

Reviewing the options, only row C correctly places energy/power in the scalar column and force/momentum in the vector column.

Final Answer: C

2. What are the base units for intensity? [1]

A $\mathrm{kg\,s^{-3}}$

B $\mathrm{kg\,s}$

C $\mathrm{kg\,m^2\,s^{-3}}$

D $\mathrm{kg\,m^4\,s^{-3}}$

Solution & Reasoning

Intensity I is defined as power P incident per unit area A. The defining equation is:

$$I = \frac{P}{A}$$

First, we derive the SI base units for Power (P = Work/time = Force $\times$ velocity):

$$\text{Units of } P = (\text{kg} \cdot \text{m} \cdot \text{s}^{-2}) \cdot (\text{m} \cdot \text{s}^{-1}) = \text{kg} \cdot \text{m}^2 \cdot \text{s}^{-3}$$

Next, substitute the base units of Area (m^2) into the intensity formula:

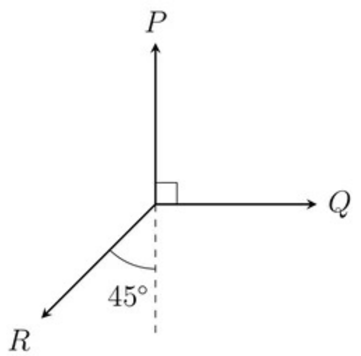
$$\text{Units of } I = \frac{\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-3}}{\text{m}^2}$$

The m^2 terms cancel out, leaving:

$$\text{Units of } I = \text{kg} \cdot \text{s}^{-3}$$

Final Answer: A

3. Three coplanar forces, P, Q and R, act at a point. [1]



The three forces are in equilibrium. The magnitude of P is increased by 10%. The directions of the forces are unchanged. Which percentage increase, if any, is required to the magnitudes of Q and R for the forces to be once again in equilibrium?

	% increase in magnitude of Q	**% increase in magnitude of R**
A	10	10
B	0	10
C	$10\sqrt{2}$	$10\sqrt{2}$
D	10	$10\sqrt{2}$

Solution & Reasoning

For three coplanar forces to be in equilibrium ($\Sigma F = 0$), their vector addition must form a closed triangle. Because the directions of the forces are strictly unchanged, the internal angles of this vector triangle are fixed. Geometrically, any new equilibrium state must form a triangle that is *similar* to the original force triangle. If one side of a triangle (force P) is scaled by a factor (increased by 10%, meaning a scale factor of 1.1), the only way to maintain a similar triangle is if all other sides (Q and R) are scaled by the exact same proportion. Therefore, both Q and R must also increase by exactly 10%.

Final Answer: A

4. A metal rod is exactly 62.00 cm long. The length of the rod is measured using two different devices, X and Y. [1]
The reading on device X is 61.5 cm.
The reading on device Y is 62.65 cm.
Which device gives the more precise reading for the length, and which device gives the more accurate reading for the length?

	more precise reading	**more accurate reading**
A	X	X
B	X	Y
C	Y	X
D	Y	Y

Solution & Reasoning

We must evaluate precision and accuracy independently:

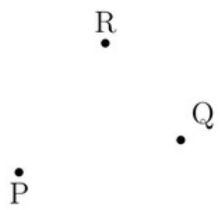
- **Precision** depends on the resolution of the instrument (number of decimal places). Device Y provides a reading to two decimal places (0.01 cm), whereas X only reads to one (0.1 cm). Thus, Y is more precise.
- **Accuracy** is determined by how close the measured value is to the true value (62.00 cm). We calculate the absolute uncertainties:

$$\text{Error for X} = |61.50 - 62.00| = 0.50 \text{ cm}$$
$$\text{Error for Y} = |62.65 - 62.00| = 0.65 \text{ cm}$$

Since Device X has a smaller deviation from the true value, it is more accurate.

Final Answer: C

5. One object moves directly from P to R. [1]



In a shorter time, a second object moves from P to Q to R. Which statement about the two objects is correct for the journey from P to R?

A They have the same average speed.

B They have the same average velocity.

C They have the same displacement.

D They travel the same distance.

Solution & Reasoning

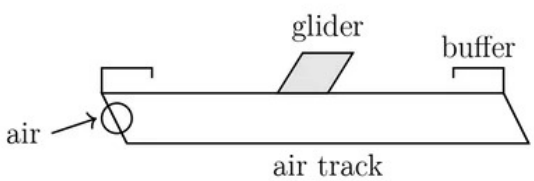
Let's define the fundamental kinematic terms for these two journeys:

- **Displacement** is a vector pointing from the initial position to the final position, independent of the path taken. Since both objects start at point P and terminate at point R, their total displacements are identical.
- **Distance** is a scalar representing the total path length. By the triangle inequality, path $P \to Q \to R$ is longer than the direct path $P \to R$.
- **Average Velocity** is $\frac{\text{displacement}}{\text{time}}$. Since they have the same displacement but different times, their average velocities differ.

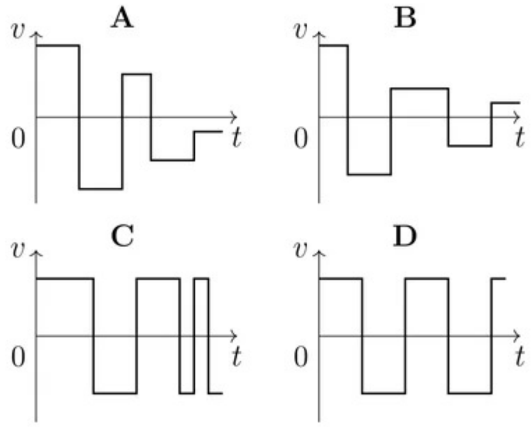
Therefore, the only shared property is their displacement.

Final Answer: C

6. A small glider moves along a horizontal air track as shown. At each end of the air track, the glider has a perfectly elastic collision with a fixed buffer. The glider moves at a constant speed between collisions. [1]



Which graph represents the variation with time t of the velocity v of the glider as it moves between the two buffers?

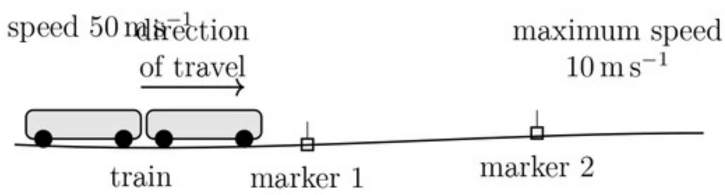


Solution & Reasoning

1. Constant speed between collisions: This implies the acceleration is zero, so the velocity-time graph must be composed of horizontal lines (v = constant).
2. Perfectly elastic collisions: Kinetic energy is conserved, meaning the rebound speed equals the impact speed. Thus, the magnitude of the velocity ($|v|$) must remain constant throughout the journey, which eliminates graphs A and B where the amplitude decays.
3. Constant time intervals: Since the distance between buffers is fixed and the speed is constant, the time $t = d/|v|$ taken for each traverse must be identical. Graph C has unequal time intervals, whereas Graph D shows a perfect square wave with equal periods.

Final Answer: D

7. The diagram shows an arrangement to stop trains that are travelling too fast. [1]



Trains coming from the left travel at a speed of $50\,\mathrm{m\,s^{-1}}$. At marker 1, the driver must apply the brakes so that the train decelerates uniformly in order to pass marker 2 at no more than $10\,\mathrm{m\,s^{-1}}$. The train carries a detector that notes the times when the train passes each marker and will apply an emergency brake if the time between passing marker 1 and marker 2 is less than 20 s.
How far from marker 2 should marker 1 be placed?

A 200 m

B 400 m

C 500 m

D 600 m

Solution & Reasoning

Use the kinematic equation that relates displacement, initial velocity, final velocity, and time for uniform deceleration:

$$s = \frac{1}{2}(u+v)t$$

Substitute the given boundary condition values (minimum time $t = 20\,\mathrm{s}$ at speeds $u = 50\,\mathrm{m\,s^{-1}}$ and $v = 10\,\mathrm{m\,s^{-1}}$):

$$s = \frac{1}{2}(50+10) \times 20 = \frac{1}{2}(60) \times 20 = 600\,\mathrm{m}$$

Final Answer: D

8. An experiment is performed to measure the acceleration of free fall g. A body falls between two fixed points. Four measurements are taken. [1]
Which measurement is **not** required for the calculation of g?

A the distance fallen by the body

B the initial velocity of the body

C the mass of the body

D the time taken for the body to fall

Solution & Reasoning

The kinematic equation describing uniform acceleration in free fall is $s = ut + \frac{1}{2}gt^2$. To isolate and find g, we require the distance fallen (s), initial velocity (u), and time taken (t). According to Galilean equivalence principle, the acceleration of free fall g in a vacuum (or neglecting air resistance as implied in basic free-fall kinematic calculations) is completely independent of the mass of the object. Therefore, mass is not required.

Final Answer: C

9. What is the definition of linear momentum? [1]

A force per unit time

B mass per unit velocity

C product of force and time

D product of mass and velocity

Solution & Reasoning

By classical Newtonian mechanics definition, the linear momentum (p) of an object is defined directly as the product of its mass (m) and its velocity (v).

$$p = m \times v$$

Final Answer: D

10. A hollow steel object is dropped from rest in air. The object reaches a terminal velocity v before hitting the ground. [1]
Which change results in an increase in the terminal velocity?

A Drop a solid steel object of the same dimensions from the same height.

B Drop the object from a greater height.

C Throw the object downwards from the same height with an initial velocity $0.5v$.

D Throw the object upwards from the same height with an initial velocity $0.5v$.

Solution & Reasoning

Terminal velocity occurs when the downward force of gravity ($W = mg$) is perfectly balanced by the upward force of air resistance ($F \approx kv^2$, where k depends on shape/dimensions).

$$mg = kv_{\text{term}}^2 \implies v_{\text{term}} = \sqrt{\frac{mg}{k}}$$

A solid steel object of the exact same dimensions has a much larger mass m but the same aerodynamic drag coefficient (k). To balance this significantly larger weight, a much higher air resistance is needed, which consequently requires a higher terminal velocity.

Final Answer: A

11. A bowling ball of mass 4.50 kg falls a short distance vertically into a tray of sand. The bowling ball decelerates uniformly in the sand. The deceleration of the bowling ball when it is in contact with the sand is $8.00 \times 10^2\,\mathrm{m\,s^{-2}}$. [1]
What is the magnitude of the force exerted on the bowling ball by the sand as it decelerates?

A 44.1 N

B 3560 N

C 3600 N

D 3640 N

Solution & Reasoning

Let F_s be the upward force exerted by the sand on the ball, and $W = mg$ be the downward weight of the ball. The ball experiences an upward resultant acceleration a. Applying Newton's Second Law ($F_{\text{net}} = ma$) in the upward direction:

$$F_s - mg = ma \implies F_s = m(a + g)$$

Substitute the values ($m = 4.50\,\text{kg}$, $a = 800\,\text{m}\,\text{s}^{-2}$, $g = 9.81\,\text{m}\,\text{s}^{-2}$):

$$F_s = 4.50 \times (800 + 9.81) = 4.50 \times 809.81 = 3644.145\,\text{N}$$

Rounded to 3 significant figures, this is $3640\,\text{N}$.

Final Answer: D

12. Which statement is **not** a requirement of a pair of forces that obey Newton's third law of motion? [1]

A The forces act in opposite directions.

B The forces act on different objects.

C The forces act on objects in contact.

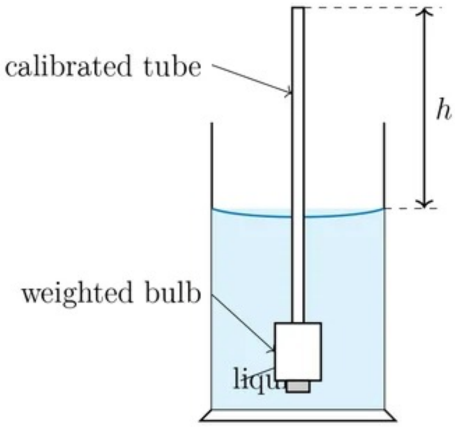
D The forces are of equal magnitude.

Solution & Reasoning

Newton's third law states that if body A exerts a force on body B, body B will exert an equal and opposite force on body A (same type of force, equal magnitude, opposite direction, acting on different bodies). This law applies universally to both contact forces (like normal reaction or friction) and non-contact forces (like gravitational attraction or electrostatic forces). Therefore, physical contact is not a requirement.

Final Answer: C

13. A hydrometer is a device for measuring the density of liquids. It consists of a weighted bulb at the bottom of a calibrated tube. The hydrometer is floating in a liquid at room temperature. The length of the tube above the level of the liquid is h. [1]



Which change causes h to decrease?

A adding more liquid into the cylinder

B decreasing the density of the liquid

C increasing the air pressure above the liquid

D increasing the density of the liquid

Solution & Reasoning

The hydrometer is in a state of floating equilibrium. This means its downward Weight (W) must equal the upward Buoyant Force (U).
$W = U = \rho_{\text{liquid}} \cdot V_{\text{submerged}} \cdot g$
The weight of the hydrometer W is a fixed constant.
If h decreases, it physically means the hydrometer has sunk deeper into the liquid. Consequently, the submerged volume $V_{\text{submerged}}$ increases.
In order to keep the product ($\rho_{\text{liquid}} \times V_{\text{submerged}}$) constant while $V_{\text{submerged}}$ increases, the density of the liquid ρ_{liquid} must decrease.

Final Answer: B

14. Torque is the result of a pair of forces acting to cause a turning effect. Torque is calculated as the product of force and distance. [1]
Which row gives the correct description of the force and the distance used to calculate the torque of a couple?

	force	**distance**
A	the magnitude of one force	the perpendicular distance between the two forces
B	the sum of the magnitudes of both forces	the perpendicular distance between the two forces
C	the magnitude of one force	the perpendicular distance from one force to the mid-point between the forces
D	the resultant of the two forces	the perpendicular distance from one force to the mid-point between the forces

Solution & Reasoning

By standard physical definition, a couple consists of two equal, anti-parallel forces whose lines of action do not coincide. The torque (or moment) T produced by a couple is calculated as the product of the magnitude of **one** of the forces (F) and the total **perpendicular distance** (d) between the lines of action of the two forces. ($T = F \times d$).

Final Answer: A

15. The density of paper is $800\,\mathrm{kg\,m^{-3}}$. A typical sheet of paper has a width of 210 mm and a length of 300 mm. The thickness of a pack of 500 sheets of paper is 50 mm. [1]
What is the mass of a single sheet of paper?

A 0.5 g

B 5 g

C 50 g

D 500 g

Solution & Reasoning

First, find the thickness of a single sheet:
$t = 50\,\mathrm{mm}/500 = 0.1\,\mathrm{mm} = 10^{-4}\,\mathrm{m}$.
Next, calculate the volume V of a single sheet:
$V = \text{length} \times \text{width} \times \text{thickness}$
$V = (0.300\,\mathrm{m}) \times (0.210\,\mathrm{m}) \times (10^{-4}\,\mathrm{m}) = 6.3 \times 10^{-6}\,\mathrm{m}^3$.
Finally, use the density formula to find the mass m:
$m = \rho V = (800\,\mathrm{kg\,m^{-3}}) \times (6.3 \times 10^{-6}\,\mathrm{m}^3) = 5.04 \times 10^{-3}\,\mathrm{kg}$.
Convert to grams: $5.04 \times 10^{-3}\,\mathrm{kg} = 5.04\,\mathrm{g} \approx 5\,\mathrm{g}$.

Final Answer: B

16. Which statement about equilibrium is correct? [1]

A If a system is in equilibrium then there must be no forces acting on it.

B If a system is in equilibrium then there must be no resultant torque on it.

C If there are no moments due to forces acting on a system then it must be in equilibrium.

D If there is no resultant force acting on a system then it must be in equilibrium.

Solution & Reasoning

For a system to be in complete static equilibrium, two strict conditions must be met simultaneously: 1) There must be no resultant force ($\Sigma F = 0$). 2) There must be no resultant torque or moment ($\Sigma M = 0$).
Options C and D only satisfy one of the two conditions, which is insufficient. Option A is incorrect because forces can act on the system as long as they balance out. Option B is a true consequence: if it is in equilibrium, the resultant torque *must* be zero.

Final Answer: B

17. An object of weight 3.0 N is moved vertically at a constant velocity v by an electric motor. The electric motor has an efficiency of 25%. The object travels a vertical distance of 1.2 m in 3.0 s. Assume that the useful output energy of the motor is equal to the increase in gravitational potential energy of the object. [1]
What is the electric power supplied to the motor?

A 0.3 W

B $1.2\,\mathrm{W}$

C $4.8\,\mathrm{W}$

D $30\,\mathrm{W}$

Solution & Reasoning

First, calculate the useful output power (P_{out}) which is the rate of gaining gravitational potential energy:
$P_{\text{out}} = \frac{\Delta E_p}{t} = \frac{mgh}{t} = \frac{W \times h}{t} = \frac{3.0\,\mathrm{N} \times 1.2\,\mathrm{m}}{3.0\,\mathrm{s}} = 1.2\,\mathrm{W}$.
Next, relate output power to input electric power using the efficiency formula:
$\text{Efficiency} = \frac{P_{\text{out}}}{P_{\text{in}}} \implies 0.25 = \frac{1.2}{P_{\text{in}}}$
$P_{\text{in}} = \frac{1.2}{0.25} = 4.8\,\mathrm{W}$.

Final Answer: C

18. An alpha particle has $2.2 \times 10^{-13}\,\mathrm{J}$ of kinetic energy. What is the speed of the alpha particle? [1]

A $4.1 \times 10^{6}\,\mathrm{m\,s^{-1}}$

B $5.8 \times 10^{6}\,\mathrm{m\,s^{-1}}$

C $8.1 \times 10^{6}\,\mathrm{m\,s^{-1}}$

D $1.2 \times 10^{7}\,\mathrm{m\,s^{-1}}$

Solution & Reasoning

The mass of an alpha particle (a helium nucleus with 2 protons and 2 neutrons) is approximately $4\,\mathrm{u}$ (unified atomic mass units).
$m \approx 4 \times (1.66 \times 10^{-27}\,\mathrm{kg}) = 6.64 \times 10^{-27}\,\mathrm{kg}$.
Using the kinetic energy formula $E_k = \frac{1}{2}mv^2$:
$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times (2.2 \times 10^{-13})}{6.64 \times 10^{-27}}} \approx 8.14 \times 10^{6}\,\mathrm{m\,s^{-1}}$.

Final Answer: C

19. An initially unstretched spring is stretched within its limit of proportionality to a length of $80\,\mathrm{mm}$. The work done stretching the spring is $0.010\,\mathrm{J}$. The spring constant of the spring is $22.5\,\mathrm{N\,m^{-1}}$. [1]
What is the unstretched length of the spring?

A $30\,\mathrm{mm}$

B $50\,\mathrm{mm}$

C $60\,\mathrm{mm}$

D $110\,\mathrm{mm}$

Solution & Reasoning

The work done (elastic potential energy) is given by $W = \frac{1}{2}kx^2$, where x is the extension.
$0.010 = \frac{1}{2}(22.5)x^2 \implies x^2 = \frac{0.020}{22.5} \approx 8.889 \times 10^{-4}\,\text{m}^2$.
$x = \sqrt{8.889 \times 10^{-4}} \approx 0.0298\,\text{m} \approx 30\,\text{mm}$.
Since Final Length = Unstretched Length + Extension:
Unstretched Length $= 80\,\text{mm} - 30\,\text{mm} = 50\,\text{mm}$.

Final Answer: B

20. What is meant by elastic deformation of a wire under tension? [1]

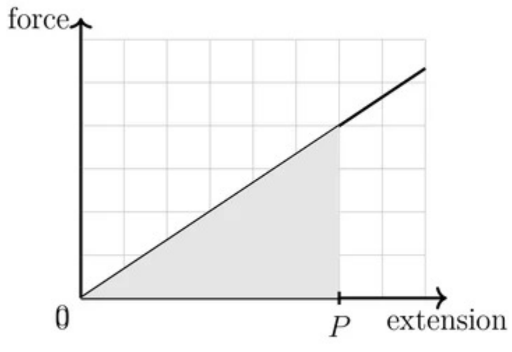
A deformation for which the elastic potential energy is proportional to the extension
B deformation for which the extension is proportional to the tensile force
C deformation for which the extension remains constant as the tensile force is removed
D deformation for which the extension returns to zero when the tensile force is removed

Solution & Reasoning

Elastic deformation is fundamentally defined by a material's capability to return to its original shape and size once the applied deforming forces are removed. Option B describes Hooke's Law, not the general definition of elastic deformation. Option D correctly describes the defining characteristic of elastic behavior.

Final Answer: D

21. The graph shows the variation of force with extension for a metal object deformed within its limit of proportionality. [1]



What does the shaded area represent?

A the elastic limit of the object
B the elastic potential energy stored in the object at an extension of P
C the spring constant of the object
D the Young modulus of the metal at an extension of P

Solution & Reasoning

The area under a force-extension graph corresponds to the integral $\int F\,dx$. Geometrically, this area represents the work done by the force in stretching the object. Assuming it behaves elastically, this work done is entirely stored as elastic potential energy.

Final Answer: B

22. What is the order of these principal regions of the electromagnetic spectrum from shortest to longest wavelength? [1]

A infrared radiation, visible light, ultraviolet radiation

B ultraviolet radiation, infrared radiation, visible light

C ultraviolet radiation, visible light, infrared radiation

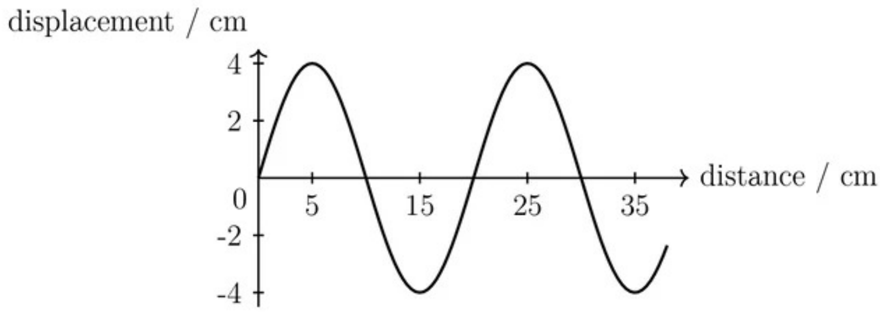
D visible light, ultraviolet radiation, infrared radiation

Solution & Reasoning

The standard order of the electromagnetic spectrum from highest frequency (shortest wavelength) to lowest frequency (longest wavelength) is: Gamma rays, X-rays, Ultraviolet (UV), Visible light, Infrared (IR), Microwaves, Radio waves. Thus, the correct sequence from shortest to longest wavelength is UV $\rightarrow$ Visible $\rightarrow$ IR.

Final Answer: C

23. The graph shows the displacement of each particle in a transverse wave against distance at one instant in time. [1]



The speed of the wave is $1.6\,\mathrm{m\,s^{-1}}$. What is the frequency of the wave?

A 0.050 Hz

B 0.080 Hz

C 5.0 Hz

D 8.0 Hz

Solution & Reasoning

From the displacement-distance graph, the wavelength (λ) is the physical distance over one complete cycle. A full cycle spans from $x = 5\,\text{cm}$ to $x = 25\,\text{cm}$.
$\lambda = 25\,\text{cm} - 5\,\text{cm} = 20\,\text{cm} = 0.20\,\text{m}$.
Using the wave equation $v = f\lambda$, we can solve for frequency f:
$f = \frac{v}{\lambda} = \frac{1.6\,\text{m}\,\text{s}^{-1}}{0.20\,\text{m}} = 8.0\,\text{Hz}$.

Final Answer: D

24. The siren on an emergency vehicle emits a sound of constant frequency 1100 Hz. The driver in a stationary car hears the sound at a frequency of 1000 Hz. The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$. [1]
What is the velocity of the emergency vehicle?

A $31\,\text{m}\,\text{s}^{-1}$ away from the stationary car

B $34\,\text{m}\,\text{s}^{-1}$ away from the stationary car

C $31\,\text{m}\,\text{s}^{-1}$ towards the stationary car

D $34\,\text{m}\,\text{s}^{-1}$ towards the stationary car

Solution & Reasoning

Because the observed frequency ($f_o = 1000\,\text{Hz}$) is **lower** than the source frequency ($f_s = 1100\,\text{Hz}$), the vehicle must be moving **away** from the observer (Doppler red-shift).
Using the Doppler effect equation for a receding source:

$$f_o = f_s\left(\frac{v}{v + v_s}\right)$$

$$1000 = 1100\left(\frac{340}{340 + v_s}\right)$$

$$\frac{1000}{1100} = \frac{340}{340 + v_s} \implies 340 + v_s = 1.1 \times 340 = 374$$

$$v_s = 374 - 340 = 34\,\text{m}\,\text{s}^{-1}$$

Final Answer: B

25. A source of sound of constant power P is situated in an open space. The intensity I of sound at distance r from this source is given by the equation shown. [1]

$$I = \frac{P}{4\pi r^2}$$

How does the amplitude a of the vibrating air molecules vary with the distance r from the source?

A $a \propto \frac{1}{r}$

B $a \propto \frac{1}{r^2}$

C $a \propto r$

D $a \propto r^2$

Solution & Reasoning

From the given equation, intensity obeys the inverse square law: $I \propto \frac{1}{r^2}$.
A fundamental property of waves is that intensity is directly proportional to the square of the amplitude: $I \propto a^2$.
Equating the two proportionalities yields:

$$a^2 \propto \frac{1}{r^2} \implies a \propto \frac{1}{r}$$

Final Answer: A

26. Water waves diffract as they pass through a gap. Which combination produces the greatest amount of diffraction? [1]

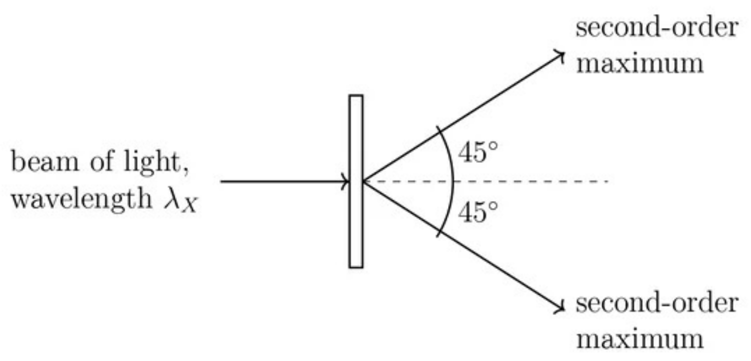
	wavelength / m	**gap width / m**
A	10^{-1}	10^{0}
B	10^{-1}	10^{-2}
C	10^{0}	10^{0}
D	10^{0}	10^{2}

Solution & Reasoning

According to CIE standard physics principles, the most significant diffraction (broadest geometrical spreading forming a semi-circular wavefront with sufficient transmitted energy) occurs when the gap width w is approximately equal to the wavelength λ.
Option C features $\lambda = 10^0\,\text{m}$ and $w = 10^0\,\text{m}$, satisfying the maximum diffraction condition $\lambda \approx w$.

Final Answer: C

27. The diagram shows a beam of light of wavelength λ_X that is incident normally on a diffraction grating. [1]



The diagram shows only the second-order intensity maxima that are produced at an angle of 45° to the direction of the incident beam of light. A replacement beam of light of a different wavelength λ_Y is now incident normally on the diffraction grating. This new wavelength also produces intensity maxima that are at an angle of 45° to the direction of the incident beam of light.
What is a possible value of the ratio $\frac{\lambda_X}{\lambda_Y}$?

A 0.25

B 0.75

C 1.25

D 1.50

Solution & Reasoning

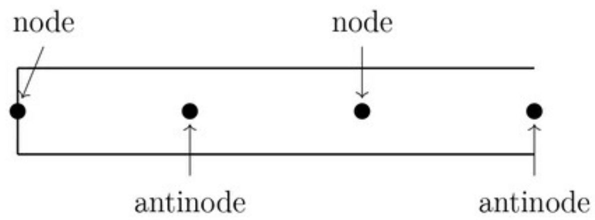
Apply the diffraction grating equation: $d \sin\theta = n\lambda$.
For the first beam (λ_X), the 2$^{\text{nd}}$ order maximum is at 45°: $d\sin(45°) = 2\lambda_X$.
For the second beam (λ_Y), an unknown order m also produces a maximum at 45°: $d\sin(45°) = m\lambda_Y$.
Equating the two expressions:

$$2\lambda_X = m\lambda_Y \implies \frac{\lambda_X}{\lambda_Y} = \frac{m}{2}$$

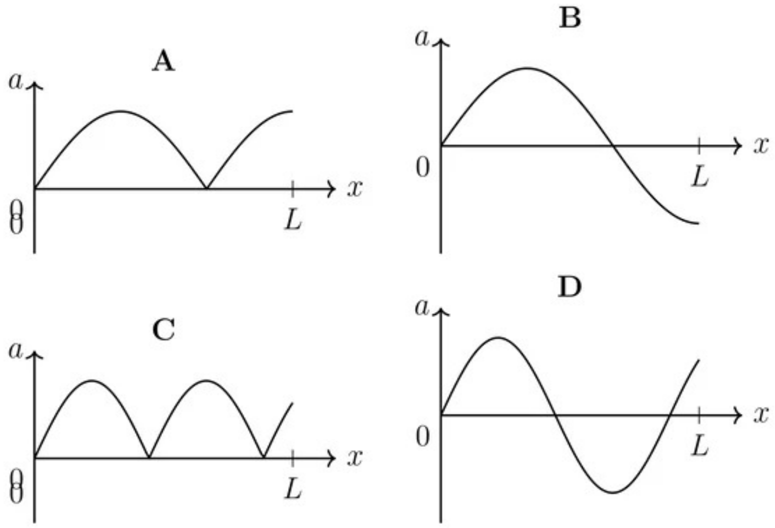
Since the order m must be an integer $(1, 2, 3, \dots)$, the possible ratios are $\frac{1}{2}, \frac{2}{2}, \frac{3}{2}, \frac{4}{2} \dots$
Among the choices, 1.50 corresponds to $m = 3$.

Final Answer: D

28. A stationary sound wave is formed in a tube of length L that is closed at one end. The diagram shows the positions of the nodes and antinodes of the stationary wave. [1]



Which graph shows the variation of the amplitude a of the wave with distance x measured from the closed end of the tube?



Solution & Reasoning

1. Amplitude vs Displacement: Amplitude a is a scalar quantity representing the maximum magnitude of displacement. Thus, a graph of amplitude can never be negative ($a \geq 0$). This eliminates graphs B and D, which show momentary instantaneous displacement plunging into negative values.
2. Node/Antinode Count: The physical tube diagram clearly dictates the sequence: Closed End (Node) $\rightarrow$ Antinode $\rightarrow$ Middle Node $\rightarrow$ Open End (Antinode). This equates to exactly 1.5 half-wavelength "humps". Graph A perfectly maps this N-A-N-A sequence, hitting exactly two zero-amplitude nodes. Graph C shows an excessive N-A-N-A-N-A pattern (too many nodes).

Final Answer: A

29. Waves are emitted by two coherent sources. The two waves meet at point X where they have a constant phase difference of 180°. [1]
At point X, the amplitude of one of the waves is 0.50 m and the amplitude of the other wave is 0.30 m. The waves superpose. What is the amplitude of the resultant wave at point X?

A 0 m

B 0.20 m

C 0.40 m

D 0.80 m

Solution & Reasoning

A constant phase difference of 180° implies the waves are in perfect anti-phase, resulting in strictly destructive interference.
The resultant amplitude is derived by subtracting the smaller amplitude from the larger one:
$A_{\text{net}} = |A_1 - A_2| = |0.50\,\text{m} - 0.30\,\text{m}| = 0.20\,\text{m}$.

Final Answer: B

30. There is a current in a resistor for an unknown time. [1]
Which two quantities can be used to calculate the energy dissipated by the resistor?

A the current in the resistor and the potential difference across the resistor

B the resistance of the resistor and the current in the resistor

C the total charge passing through the resistor and the potential difference across the resistor

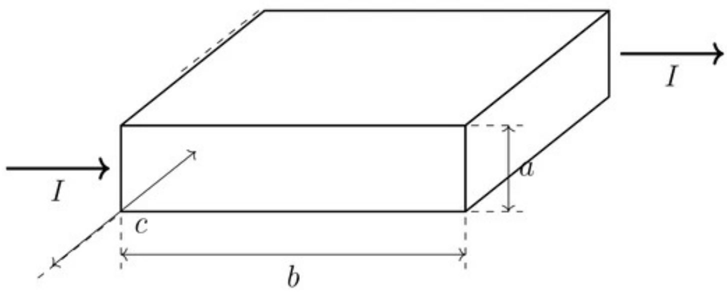
D the total charge passing through the resistor and the resistance of the resistor

Solution & Reasoning

Standard electrical energy equations generally depend on the time interval (t): $E = VIt$, $E = I^2Rt$, or $E = \frac{V^2}{R}t$.
However, the time is stated as *unknown*. Therefore, we must rely on the definition of potential difference: $V = \frac{E}{Q}$, which rearranges to $E = VQ$.
This formula calculates total energy using only total charge (Q) and potential difference (V).

Final Answer: C

31. The diagram shows a metal block. [1]



The block has sides of length a, b and c as shown, and its volume is V. Each charge carrier has a charge $-q$ and the number density of the charge carriers in the metal is n. It takes each charge carrier an average time of t to pass through the block.
What is an expression for the current I?

A $I = nqabc$ **B** $I = \dfrac{nqV}{t}$ **C** $I = \dfrac{nqbc}{t}$ **D** $I = nqaV$

Solution & Reasoning

Current (I) is defined as the rate of flow of electric charge: $I = \frac{\Delta Q}{t}$.
The total number of charge carriers (N) inside the block is the product of the number density (n) and the total volume (V): $N = n \times V$.
Since each individual carrier has a charge of magnitude q, the total charge ΔQ passing through the block is: $\Delta Q = N \times q = nVq$.
Substituting this back into the current equation gives: $I = \frac{nqV}{t}$.

Final Answer: B

32. An electrical component is connected into a circuit. Which component and which change causes an increase in the resistance of the component? [1]

	component	change
A	filament lamp	increase in electric current
B	light-dependent resistor (LDR)	increase in light intensity
C	semiconductor diode	increase in electric current
D	thermistor	increase in temperature

Solution & Reasoning

Let's analyze each component:

- **Filament lamp:** An increase in current heats up the metal filament. The increased temperature causes greater lattice vibrations, which scatter electrons more frequently, thereby **increasing** the resistance.
- **LDR:** Increasing light intensity releases more charge carriers, *decreasing* resistance.
- **Thermistor (NTC):** Increasing temperature releases more charge carriers, *decreasing* resistance.

Final Answer: A

33. A metal wire with circular cross-section has length L and diameter d. The resistance of the wire is R. The wire is now melted and reformed into a new wire of diameter $0.50d$. The volume of the wire is unchanged. [1]
What is the resistance of the new wire?

A R
B $2R$
C $4R$
D $16R$

Solution & Reasoning

The initial resistance is $R = \rho\frac{L}{A}$. The cross-sectional area A is proportional to d^2. When the diameter is halved to $0.50d$, the new area becomes:

$$A' \propto (0.50d)^2 = 0.25d^2 = \frac{1}{4}A$$

Because the volume ($V = A \times L$) remains constant, if the area is divided by 4, the length must be multiplied by 4 to compensate:

$$L' = 4L$$

Now, calculate the new resistance R':

$$R' = \rho\frac{L'}{A'} = \rho\frac{4L}{\frac{1}{4}A} = 16\left(\rho\frac{L}{A}\right) = 16R$$

Final Answer: D

34. A battery with internal resistance is connected by wires to an external resistor. Which statement describes the electromotive force (e.m.f.) of the battery? [1]

A It is the energy transferred per unit charge in driving charge through a connecting wire.

B It is the energy transferred per unit charge in driving charge through the complete circuit.

C It is the energy transferred per unit charge in driving charge through the external resistor.

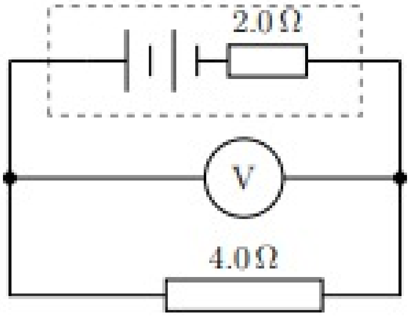
D It is the energy transferred per unit charge in driving charge through the internal resistance.

Solution & Reasoning

The fundamental definition of electromotive force (e.m.f.) is the total energy converted from non-electrical forms into electrical energy per unit charge. This energy is used to drive the charge around the **complete circuit**, which includes both the external load (resistors, wires) and the internal resistance of the battery itself. Options A, C, and D describe potential differences (p.d.) across specific components.

Final Answer: B

35. The diagram shows a circuit with a battery connected to a resistor with a resistance of $4.0\,\Omega$. [1]



The battery has an internal resistance of 2.0 Ω. The voltmeter reads 12 V. A second resistor of resistance 4.0 Ω is connected in parallel to the first resistor.
What is the new reading on the voltmeter?

A 6.0 V

B 9.0 V

C 12 V

D 24 V

Solution & Reasoning

Step 1: Determine the e.m.f. (E) of the battery.
The voltmeter measures the terminal potential difference across the external 4.0 Ω resistor. The initial current is $I_1 = \frac{V}{R} = \frac{12\,\text{V}}{4.0\,\Omega} = 3.0\,\text{A}$.
The total e.m.f. is $E = I_1(R_{\text{ext}} + r) = 3.0(4.0 + 2.0) = 18\,\text{V}$.
Step 2: Calculate the new state.
A second 4.0 Ω resistor is added in parallel. The new external equivalent resistance is: $R'_{\text{ext}} = \frac{4.0}{2} = 2.0\,\Omega$.
The new total current is $I_2 = \frac{E}{R'_{\text{ext}}+r} = \frac{18}{2.0+2.0} = 4.5\,\text{A}$.
The new voltmeter reading (new terminal p.d.) is $V' = I_2 \times R'_{\text{ext}} = 4.5 \times 2.0 = 9.0\,\text{V}$.

Final Answer: B

36. Kirchhoff's first and second laws are a consequence of the conservation of different quantities. What are those quantities? [1]

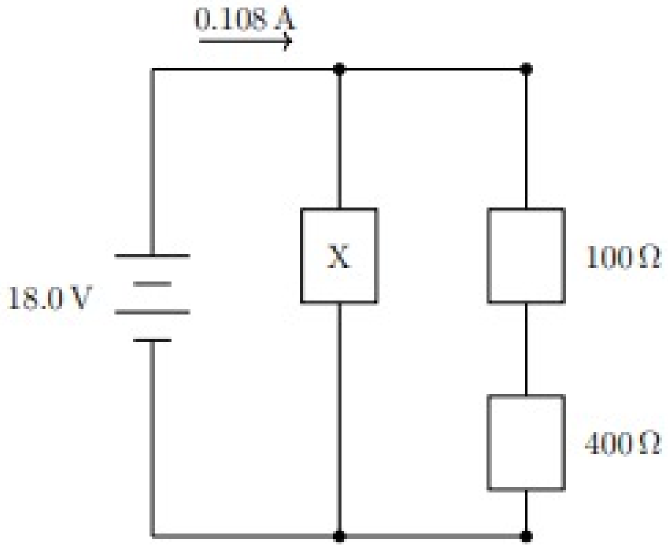
	Kirchhoff's first law	**Kirchhoff's second law**
A	charge	energy
B	energy	current
C	current	charge
D	energy	charge

Solution & Reasoning

Kirchhoff's First Law (junction rule: $\Sigma I = 0$) states that current flowing into a node must equal current flowing out, which is a direct consequence of the **conservation of charge**.
Kirchhoff's Second Law (loop rule: Σe.m.f. = Σp.d.) states that the sum of voltage changes around any closed loop is zero, which is a direct consequence of the **conservation of energy**.

Final Answer: A

37. A battery of electromotive force (e.m.f.) 18.0 V and negligible internal resistance is connected to a network of three fixed resistors as shown. [1]



The current in the battery is 0.108 A. What is the resistance of resistor X?

A 125 Ω

B 167 Ω

C 250 Ω

D 500 Ω

Solution & Reasoning

The circuit features two parallel branches connected directly across an ideal 18.0 V battery.

Step 1: Calculate the current in the right branch.

The total resistance of the right branch is $R_{\text{right}} = 100\,\Omega + 400\,\Omega = 500\,\Omega$.

Using Ohm's law, the current passing through it is:

$$I_{\text{right}} = \frac{V}{R_{\text{right}}} = \frac{18.0\,\text{V}}{500\,\Omega} = 0.036\,\text{A}$$

Step 2: Determine current through X using Kirchhoff's 1st Law.

The total main circuit current splits at the top junction: $I_{\text{total}} = I_X + I_{\text{right}}$.

$$0.108\,\text{A} = I_X + 0.036\,\text{A} \implies I_X = 0.072\,\text{A}$$

Step 3: Calculate resistance of X.

Resistor X also receives the full 18.0 V potential difference.

$$R_X = \frac{V}{I_X} = \frac{18.0\,\text{V}}{0.072\,\text{A}} = 250\,\Omega$$

Final Answer: C

38. A nucleus P undergoes β^+ decay, becoming nucleus Q and emitting two particles X and Y as shown. [1]

$$\text{P} \rightarrow \text{Q} + \text{X} + \text{Y}$$

Which two particles are X and Y?

A electron and antineutrino

B electron and neutrino

C positron and antineutrino

D positron and neutrino

Solution & Reasoning

In β^+ decay (positron emission), a proton inside the nucleus converts into a neutron. To conserve charge, a positively charged **positron** (e^+ or β^+) is emitted. To conserve lepton number, an electron **neutrino** (ν_e) must also be emitted alongside the positron. (Conversely, β^- decay emits an electron and an antineutrino).

Final Answer: D

39. Which particle is a lepton? [1]

A neutrino

B proton

C strange antiquark

D up quark

Solution & Reasoning

Leptons are fundamental particles that do not participate in the strong nuclear force. Standard leptons include the electron, muon, tau, and their corresponding **neutrinos**. Protons are baryons (composed of quarks). Quarks (up, down, strange, etc.) are fundamental particles that do experience the strong force and are explicitly categorized separately from leptons.

Final Answer: A

40. A nucleus decays in a series of stages. At each stage, an α-particle or β^--particle is emitted. [1]
Which sequence of emitted particles forms a nucleus that is an isotope of the original nucleus?

A $\alpha, \alpha, \beta^-, \beta^-$

B β^-, β^-, α

C $\alpha, \alpha, \alpha, \alpha$

D $\beta^-, \beta^-, \beta^-$

Solution & Reasoning

By definition, isotopes are atoms of the same element, meaning they must have the exact same atomic number (number of protons, Z). To form an isotope, the net change in atomic number must be zero ($\Delta Z = 0$).

- Emitting one α particle (He_2^4) decreases Z by 2.
- Emitting one β^- particle (an electron, e_{-1}^0) increases Z by 1.

To return to the original Z, the losses and gains must mathematically cancel:

$$-2(\text{number of } \alpha) + 1(\text{number of } \beta^-) = 0$$

This means you need exactly **two β^- decays for every one α decay**.
Looking at the options, sequence B (β^-, β^-, α) provides $\Delta Z = (+1) + (+1) - 2 = 0$.

Final Answer: B