# SPECIMEN PAPERS

## SET 2

## Paper 1 HL

**Time allowed: 2 hours.**

**A calculator and the data booklet are required.**

**The paper consists of Section A with 40 multiple choice questions and Section B with data-based questions.**

## Section A – Multiple choice questions

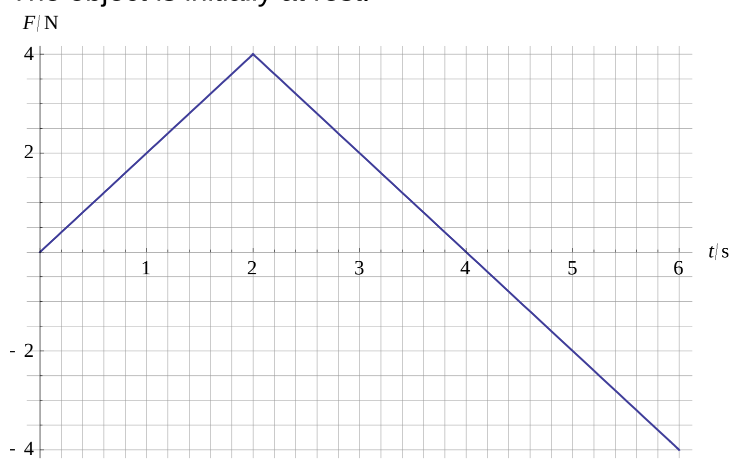
**1** A car has an initial velocity of 20 m s$^{-1}$. It decelerates at 5.0 m s$^{-2}$. After which distance will the car stop?

**A** 4.0 m **B** 40 m **C** 80 m **D** 100 m

**2** A projectile has an initial horizontal velocity of 10 m s$^{-1}$ and an initial vertical velocity of 20 m s$^{-1}$. The initial kinetic energy is *K*. What is the kinetic energy after 1 s?

**A** $\frac{K}{5}$ **B** $\frac{2}{5}K$ **C** $\frac{5}{2}K$ **D** $5K$

**3** The graph shows the variation with time *t* of the net force *F* on an object of mass 2.0 kg. The object is initially at rest.

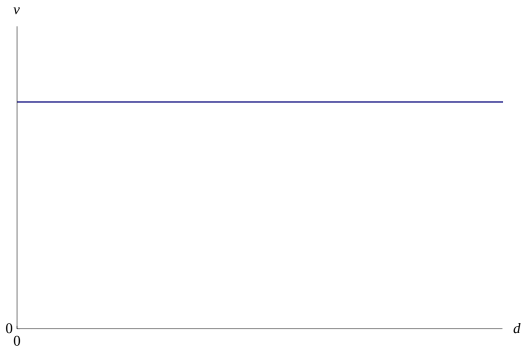



What is the velocity of the object at $t$ = 6 s?

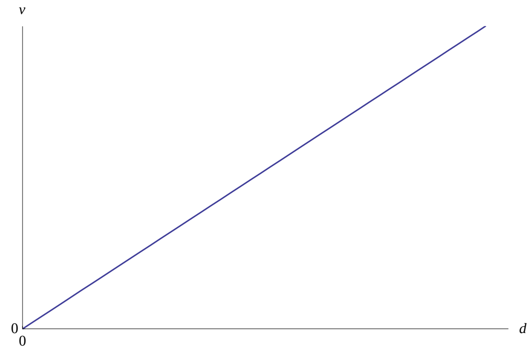
**A** 2.0 m s$^{-1}$ **B** 4.0 m s$^{-1}$ **C** 8.0 m s$^{-1}$ **D** 16 m s$^{-1}$

**4** A constant resultant force is applied to a body initially at rest.

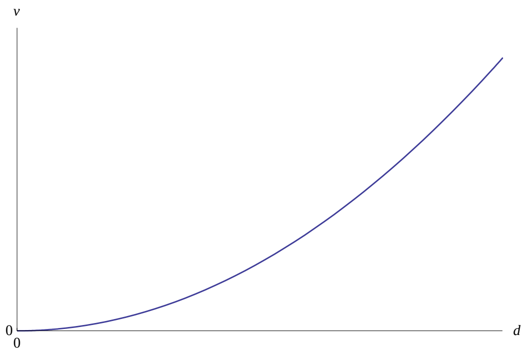
Which graph correctly shows the variation with distance travelled *d* of the speed *v*?



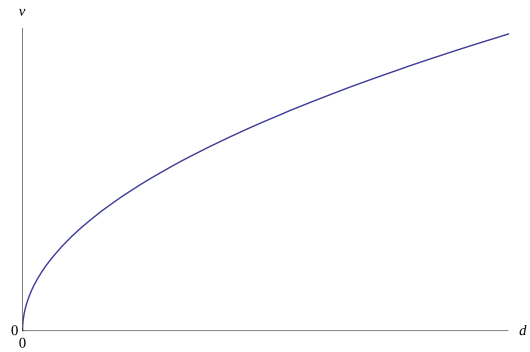

**A**




**B**




**C**




**D**

**5** A constant net force of 6.0 N accelerates a body from rest to a speed of 8.0 m $s^{-1}$. What is the average power developed by the force?

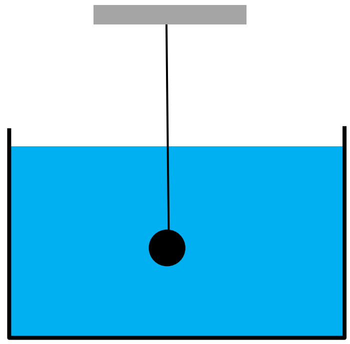
**A** 12 W

**B** 24 W

**C** 48 W

**D** It is impossible to answer without knowing the mass.

**6** A small steel ball of density $\rho_S$ is attached to a string and is fully submerged in a container filled with a liquid of density $\rho_L$.



The string is cut. What is the initial acceleration of the ball?

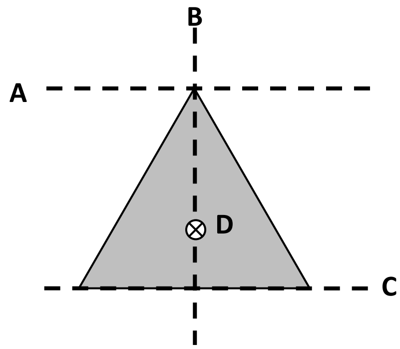
**A** $g(1+\frac{\rho_S}{\rho_L})$

**B** $g(1-\frac{\rho_S}{\rho_L})$

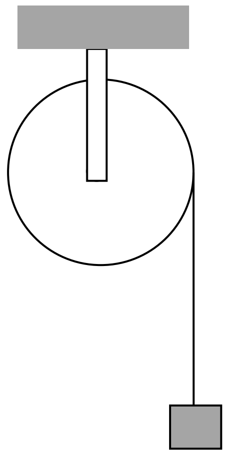
**C** $g(1+\frac{\rho_L}{\rho_S})$

**D** $g(1-\frac{\rho_L}{\rho_S})$

**7** A uniform triangular sheet can rotate about the four axes shown. About which axis is the moment of inertia the greatest?



**8** A block of mass $m$ is attached to a string that is wound around a pulley of mass $m$ and radius $R$. The moment of inertia of the pulley is $\frac{1}{2}mR^2$.



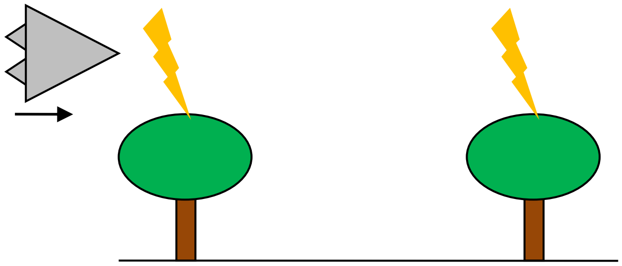
The block is released. What is its acceleration?

**A** $\frac{g}{3}$ **B** $\frac{g}{2}$ **C** $\frac{2g}{3}$ **D** $g$

**9** A spacecraft leaves earth with speed 0.80c on its way to a planet 12 ly away. These measurements are according to earth. When does the spacecraft arrive at the planet according to earth and spacecraft clocks?

| | **Earth clocks /years** | **Spacecraft clocks /years** |
|---|---|---|
| **A** | 9 | 9 |
| **B** | 9 | 15 |
| **C** | 15 | 9 |
| **D** | 15 | 15 |

**10** Two trees are hit by lightning at the same time according to an observer on the ground.



A rocket goes by at relativistic speed. What is correct for the rocket?

**A** The trees are hit by lightning at the same time.
**B** The tree on the left is hit first.
**C** The tree on the right is hit first.
**D** Any of the above can be correct depending on the position of the rocket.

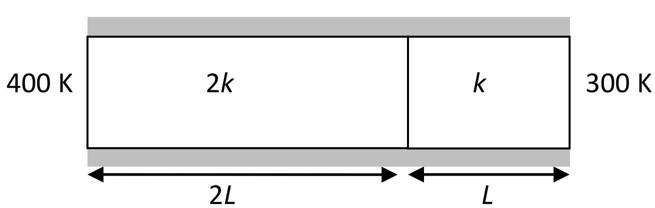
**11** Two kilograms of water at $10\ ^{\circ}\text{C}$ are mixed with one kilogram of water at $70\ ^{\circ}\text{C}$. What is the equilibrium temperature of the mixture in $^{\circ}\text{C}$?

**A** 20 **B** 30 **C** 40 **D** 50

**12** The average speed of the molecules of an ideal gas is *c*. The pressure is doubled, and the density is halved. What is the new average speed of the molecules of the gas?

**A** $c$
**B** $c\sqrt{2}$
**C** $2c$
**D** $4c$

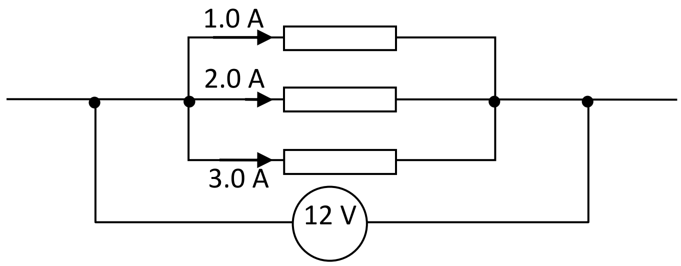
**13** Two insulated rods of the same cross-sectional area are joined. The lengths, thermal conductivities and the constant endpoint temperatures are indicated on the diagram.




What is the temperature where the rods join?

**A** 325 K **B** 350 K **C** 367 K **D** 375 K

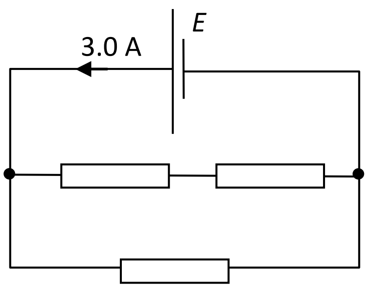
**14** The diagram shows part of a circuit. The ideal voltmeter reads 12 V.




What is the total resistance of the three resistors?

**A** 2.0 Ω **B** 4.0 Ω **C** 6.0 Ω **D** 20 Ω

**15** The cell has emf *E* and no internal resistance. It is connected to three identical resistors, each of resistance *R*. The current leaving the cell is 3.0 A.



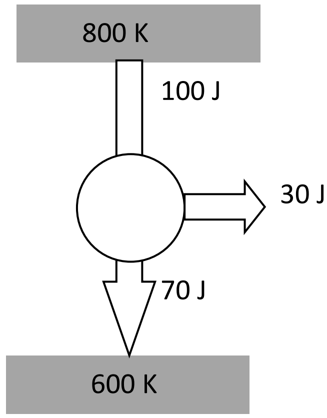

The total power dissipated in the circuit is 36 W. What is the emf of the cell and what is *R*?

| | **Emf** /V | ***R*** /Ω |
|---|---|---|
| **A** | 12 | 6.0 |
| **B** | 12 | 4.0 |
| **C** | 4.0 | 6.0 |
| **D** | 4.0 | 4.0 |

**16** When an ideal gas is compressed 500 J of work are being done. A quantity of 300 J of heat is added to the gas. What is the change in the internal energy of the gas?

**A** –200 J **B** 200 J **C** –800 J **D** 800 J

**17** What can be said about the heat engine shown?




**A** It is a perfectly possible heat engine.

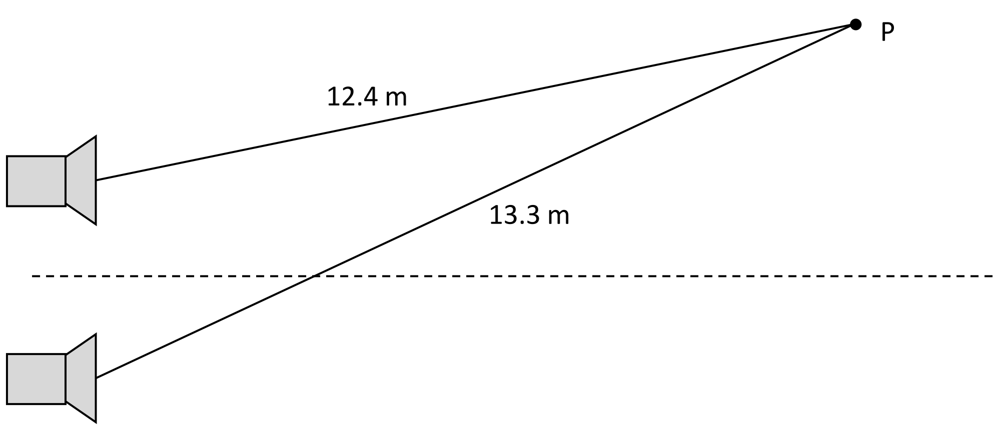
**B** It is impossible because it violates the first law of thermodynamics.

**C** It is impossible because it violates the second law of thermodynamics.

**D** It is impossible because it violates the first and second laws of thermodynamics.

**18** Two speakers emit sound of the same wavelength in phase.

Point P is at distances of 12.4 m and 13.3 m from the speakers. No sound is observed at P.




What is the shortest possible wavelength of the sound?

**A** 0.45 m **B** 0.60 m **C** 0.90 m **D** 1.8 m

**19** Monochromatic light is incident on a single slit. The intensity of the central maximum is 10 W m$^{-2}$ and the first diffraction minimum is observed at an angle of 0.10 radians. The silt width is doubled. What is the central maximum intensity and the angle of the first diffraction minimum?

| | **Intensity** /W m$^{-2}$ | **Diffraction angle** /radians |
|---|---|---|
| **A** | 20 | 0.05 |
| **B** | 20 | 0.20 |
| **C** | 40 | 0.05 |
| **D** | 40 | 0.20 |

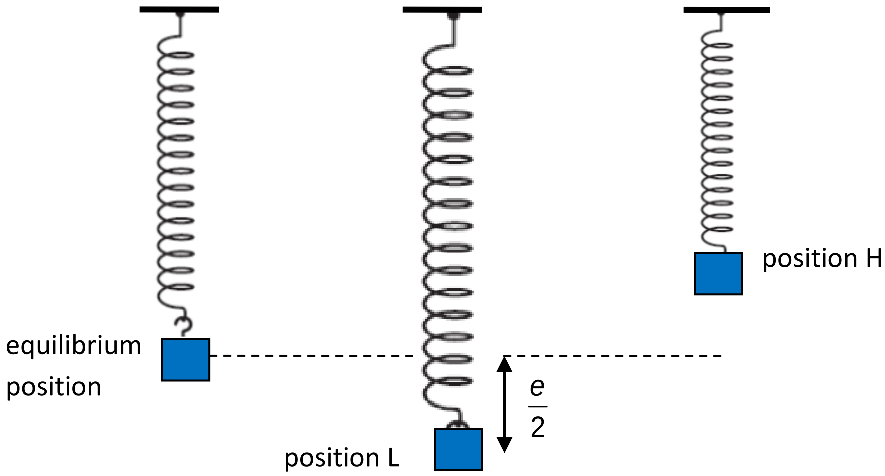
**20** A string has both ends fixed. Two **consecutive** harmonics on the string have frequencies 240 Hz and 300 Hz. What is the frequency of the first harmonic on this string?

**A** 30 Hz **B** 60 Hz **C** 120 Hz **D** 150 Hz

**21** A lightly damped oscillating system has natural frequency *f*. An external periodic force *F* of frequency 1.5*f* acts on the system. The frequency of *F* is increased. What happens to the amplitude of oscillations?

**A** It is unchanged.
**B** It decreases.
**C** It increases.
**D** It is impossible to answer with the data given.

**22** A mass hangs in equilibrium at the end of spring. At equilibrium the spring is extended by a distance *e*. The mass is pulled to position L, a distance $\frac{e}{2}$ below the equilibrium position.




When released, it performs SHM oscillations between positions L and H.

What is the ratio $\dfrac{\text{elastic potential energy at L}}{\text{elastic potential energy at H}}$?

**A** 1 **B** 3 **C** 4 **D** 9

**23** A spectral line from a source in the lab has wavelength 480 nm. The same line emitted from a galaxy has wavelength 460 nm when received on earth. What is the correct about the velocity of this galaxy? (The speed of light is *c*.)

| | Speed | Direction |
|---|---|---|
| **A** | $\frac{c}{24}$ | Away from earth |
| **B** | $\frac{c}{24}$ | Towards earth |
| **C** | $\frac{c}{23}$ | Away from earth |
| **D** | $\frac{c}{23}$ | Towards earth |

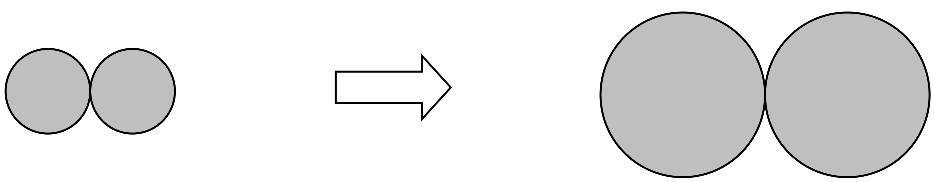
**24** An oil drop has electric charge $8.0\times10^{-19}$ C. The oil drop splits into two smaller drops of the same radius. What could be the charges on the two smaller oil drops?

| | **One drop** | **The other drop** |
|---|---|---|
| **A** | $4.0\times10^{-19}$ C | $4.0\times10^{-19}$ C |
| **B** | $1.6\times10^{-19}$ C | $4.8\times10^{-19}$ C |
| **C** | $2.0\times10^{-19}$ C | $6.0\times10^{-19}$ C |
| **D** | $4.8\times10^{-19}$ C | $3.2\times10^{-19}$ C |

**25** A potential difference is established between two parallel plates. A proton is placed on the positive plate and released. The proton reaches the negative plate with kinetic energy *K*. The potential difference and the separation of the plates are both doubled, and the experiment is repeated. What is the kinetic energy of the proton now?

**A** *K* **B** 2*K* **C** 4*K* **D** 8*K*

**26** Two identical steel spheres touch. The gravitational force between them is *F*. The spheres are replaced by two steel spheres of double the radius.



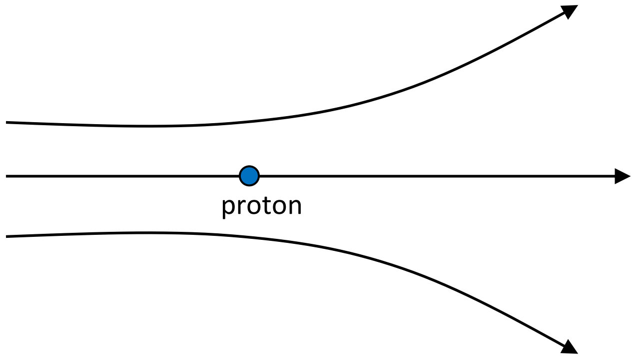
The new spheres touch. What is the force between them?

**A** $\frac{F}{4}$ **B** $\frac{F}{2}$ **C** 4*F* **D** 16*F*

**27** A planet has radius *R*. The gravitational potential at a height *R* from the surface is *V*. What is the potential at a height 2*R* from the surface?

**A** $\frac{V}{3}$ **B** $\frac{V}{2}$ **C** $\frac{2V}{3}$ **D** $\frac{3V}{2}$

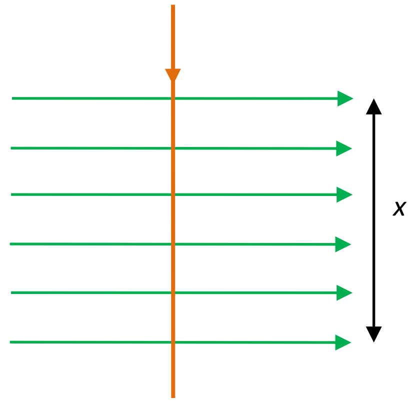
**28** A proton is placed in a region of electric field as shown and is then released.



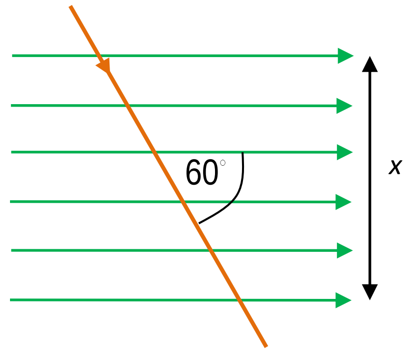

What happens to the acceleration and electrical potential energy of the proton?

| | **Acceleration** | **Electrical potential energy** |
|---|---|---|
| **A** | Increases | Increases |
| **B** | Increases | Decreases |
| **C** | Decreases | Increases |
| **D** | Decreases | Decreases |

**29** A current carrying wire experiences a magnetic force $F$ when placed in a uniform magnetic field as shown.



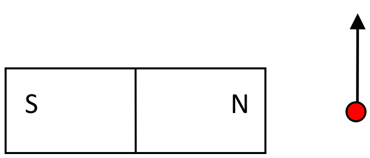

The wire is rotated so that it makes an angle of $60^\circ$ with the magnetic field.




What is the force on the wire now? ($\cos 60^\circ = \frac{1}{2}$, $\sin 60^\circ = \frac{\sqrt{3}}{2}$, $\tan 60^\circ = \sqrt{3}$)

**A** $F$ **B** $\frac{F}{2}$ **C** $\frac{F\sqrt{3}}{2}$ **D** $F\sqrt{3}$

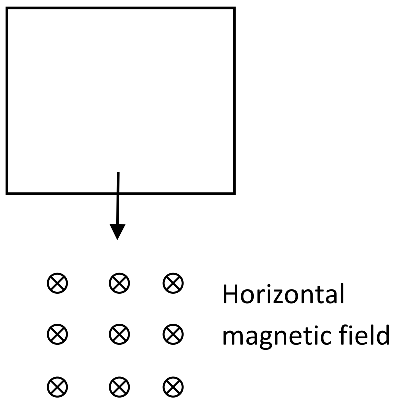
**30** An electron moves past a bar magnet.




What is the direction of the magnetic force on the electron at the position shown?

**A** Out of the page.
**B** Into the page.
**C** To the right.
**D** To the left.

**31** A conducting loop of wire is falling vertically. The loop will go through a region of uniform horizontal magnetic field.




What is the direction of the induced current in the loop as it enters and as it leaves the region of magnetic field?

| | **Enters** | **Leaves** |
|---|---|---|
| **A** | Clockwise | Clockwise |
| **B** | Clockwise | Counterclockwise |
| **C** | Counterclockwise | Clockwise |
| **D** | Counterclockwise | Counterclockwise |

**32** What was Bohr's objection to the Rutherford model of the atom?

**A** The electrons would radiate energy and plunge into the nucleus.
**B** The electrons did not follow elliptical orbits like planets around the Sun.
**C** The space between the nucleus and the electrons was empty space.
**D** In multi-electron atoms the electrons would collide with each other.

**33** A nucleus X with nucleon number *A* decays by a series of alpha and beta minus decays. The end nucleus is an isotope of X with nucleon number *A* – 8. How many $\alpha$ and $\beta^-$ decays took place?

| | **Number of $\alpha$ decays** | **Number of $\beta^-$ decays** |
|---|---|---|
| **A** | 2 | 2 |
| **B** | 2 | 4 |
| **C** | 4 | 2 |
| **D** | 4 | 4 |

**34** A proton is directed at a stationary nucleus. An alpha particle of the same kinetic energy as that of the proton is directed at the same nucleus. What is a correct comparison of the distance of closest approach and the electrical potential energy at the point of closest approach?

| | **Distance of closest approach** | **Electrical potential energy** |
|---|---|---|
| **A** | same | same |
| **B** | same | different |
| **C** | different | same |
| **D** | different | different |

**35** The initial activity of a radioactive sample X is the same as that of a sample Y. The half-life of X is $T$ and that of Y is $2T$. What is the ratio $\frac{A_X}{A_Y}$ of the activity of X to that of Y after a time of $4T$?

**A** $\frac{1}{2}$ **B** $\frac{1}{4}$ **C** 2 **D** 4

**36** The radius $r_n$ of the orbit of an electron in the $n^{th}$ state of hydrogen is given by $r_n = n^2 a_0$ where $a_0$ is a constant. What is the ratio $\frac{T_1}{T_2}$ of the period of revolution in the $n = 1$ state to that in the $n = 2$ state?

**A** $\frac{1}{2}$ **B** $\frac{1}{4}$ **C** $\frac{1}{8}$ **D** $\frac{1}{16}$

**37** A photon scatters off an electron at rest. The wavelength shift is $\frac{h}{2m_e c}$.

What is the scattering angle of the photon?

**A** $30^\circ$ **B** $45^\circ$ **C** $60^\circ$ **D** $90^\circ$

**38** An unstable nucleus has too many neutrons. What is the likely decay mode of this nucleus?

**A** Alpha decay.
**B** Beta minus decay.
**C** Beta plus decay.
**D** Gamma decay.

**39** What provides evidence for nuclear energy levels?

**A** The discrete spectrum of alpha and gamma particles in nuclear decays.
**B** The continuous spectrum of beta particles in nuclear decays.
**C** The approximate constancy of binding energy per nucleon for large nuclei.
**D** The short range of the strong nuclear force.

**40** Stars X and Y have the same luminosity. X has parallax $0.02''$ and Y has parallax $0.04''$.

What is the ratio $\frac{b_X}{b_Y}$ of the apparent brightness of X to that of Y?

**A** $\frac{1}{4}$ **B** $\frac{1}{2}$ **C** 2 **D** 4

## SECTION B – Data based questions

**1.**

Groups of students investigated the dependence of the period of a simple pendulum on the length of the pendulum.

(a) All groups used pendulum bobs of the same mass and radius under the same ambient conditions. State **one other** variable that must be controlled during the experiment. [1]

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(b) One group measured the time for a single oscillation with a stopwatch whose precision was $\pm 0.01\text{s}$ and quoted this as the uncertainty in the period. State and explain whether this is a realistic estimate of the uncertainty in the period. [2]

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(c) Another group used the stopwatch to measure the time *T* for 10 oscillations and then divided *T* by 10. State and explain an advantage for doing this. [2]

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(d) The theoretical prediction for the dependence of period on length is $T = 2\pi\sqrt{\frac{L}{g}}$ .

(i) Suggest how the data for period and length must be plotted to get a straight-line graph. [1]

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(ii) For your answer in (i), state the gradient of the straight line. [1]

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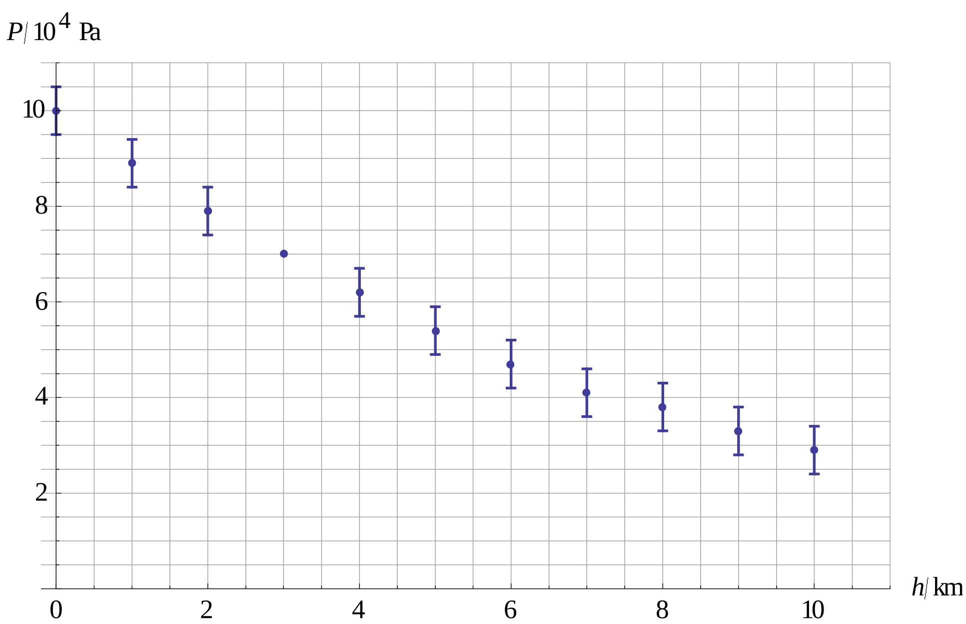
**2.**

The graph shows the variation of the atmospheric pressure *P* with height *h* above the earth's surface. The error bar for *h* = 3.0 km is not shown.




(a) State the atmospheric pressure at the surface, in the form $P \pm \Delta P$ . [1]

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(b) It is suggested that $P$ is inversely proportional to $h$. State and explain whether this is a reasonable suggestion. [2]

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(c)

(i) Draw the error bar for the data point with $h$ = 3.0 km. [1]

(ii) Determine the percentage uncertainty in $P$ for $h$ = 3.0 km. [2]

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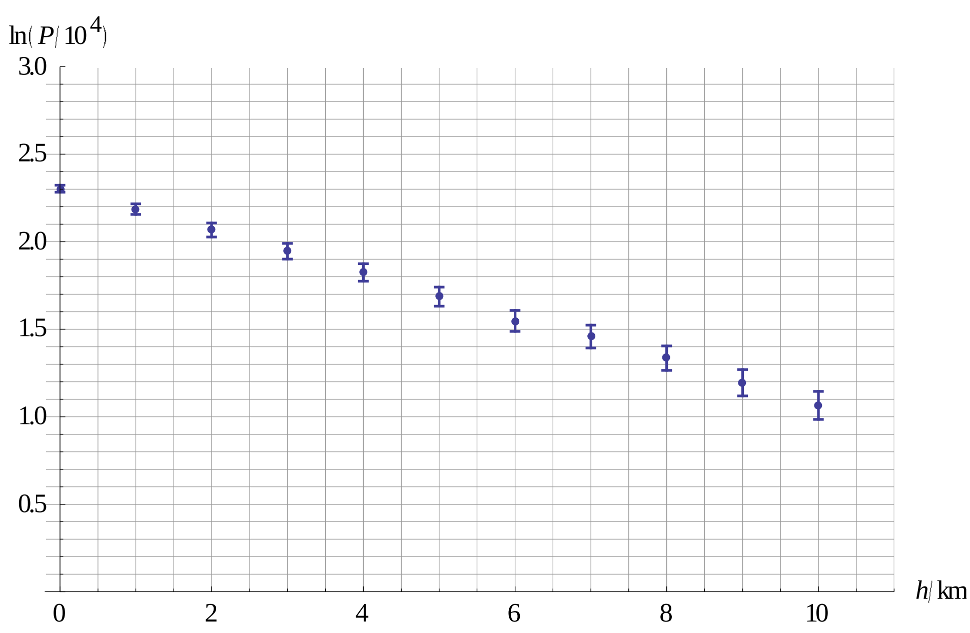
(d) The graph shows the variation of the natural logarithm of $P$ with $h$.



(i) Draw the line of best fit. [1]
(ii) Estimate the slope of the line of best fit, including its unit. [2]

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(iii) Predict the pressure at a height of 20 km. [3]

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(iv) Suggest why the estimate in (iii) may not be reliable. [1]

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# Markscheme

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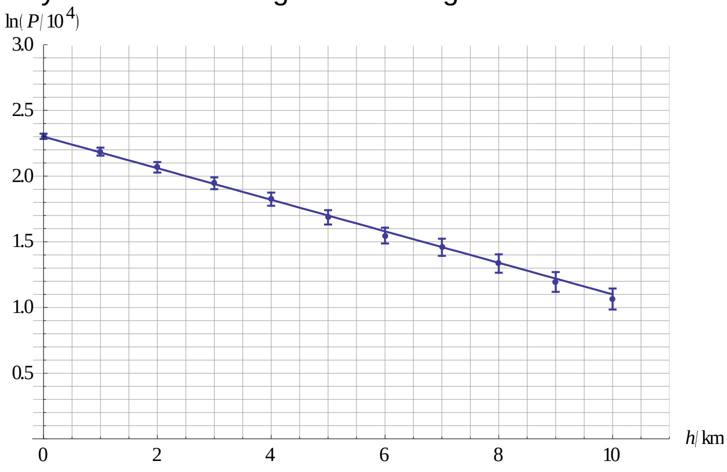
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **B** | | **11** | **B** | | **21** | **B** | | **31** | **C** |
| **2** | **B** | | **12** | **C** | | **22** | **D** | | **32** | **A** |
| **3** | **A** | | **13** | **B** | | **23** | **B** | | **33** | **B** |
| **4** | **D** | | **14** | **A**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

| **1** | | | | |
|---|---|---|---|---|
| a | | The angle by which the pendulum is displaced✓ | | [1] |
| b | | It is not✓<br>The reaction time is much greater than the precision of the stopwatch✓ | | [2] |
| c | | It reduces the random uncertainty✓<br>If the uncertainty in the measurement of the 10 oscillations is $\Delta T$ , the uncertainty in the period is $\frac{\Delta T}{10}$ ✓ | | [2] |
| d | i | $T$ vs $\sqrt{L}$ or $T^2$ vs $L$ ✓<br>$\frac{2\pi}{\sqrt{g}}$ or $\frac{4\pi^2}{g}$ ✓ | | [2] |

| **2** | | | | |
|---|---|---|---|---|
| a | | $(1.00 \pm 0.05) \times 10^5$ Pa ✓ | | [1] |
| b | | It is not✓<br><br>If it were, the pressure at the surface would be infinite✓<br>***OR***<br>$P \times h$ would be constant which it is not | | [2] |
| c | i | Vertical error bar drawn at correct place $\pm 0.5 \times 10^4$ Pa ✓ | | [1] |
| c | ii | $\frac{0.5 \times 10^4}{7.0 \times 10^4} \times 100$ ✓ | | [2] |

| | | | | |
|---|---|---|---|---|
| | | 7% ✓ | | |
| d | i | Any reasonable straight line through all error bars ✓<br> | | [1] |
| d | ii | $\frac{(1.1-2.3)}{10} = -0.12$ ✓<br>$km^{-1}$ ✓ | Accept range 0.10 to 0.14 | [2] |
| d | iii | $\ln(\frac{P}{10^4}) = 2.3 - 0.12 \times 20 = -0.10$ ✓<br>$\frac{P}{10^4} = e^{-0.10}$ ✓<br>$P = 9.0 \times 10^3$ Pa ✓ | | [3] |
| d | iv | The model is extrapolated very far from the data set ✓ | | [1] |