H2 Physics 9646 – 2016 A Level Exam

Highlight in YELLOW the recommended qns to go through in Class

Paper 1

1	No specific keywords in questions, but prefixes is the key in evaluating the answer. Answer: B
2	Keywords • Estimate (need not be exact, but choose the nearest answer) • Photon, Green light • Energy Essential Questions: • How do we calculate the energy of a photon? • What is an estimate of the wavelength of green light? Answer: C
3	Keywords • 700 km/h airspeed • 250 km/h from west • Resultant Directly North Essential Questions: • How should the aircraft fly towards so that the resultant velocity is directly north? • What is the vector diagram and what are the vectors to be drawn? (name the 3 vectors to be drawn: initial velocity of aircraft, change in velocity of caused by the wind, final/resultant velocity of the aircraft) Answer: B
4	Keywords • velocity-time graph • displacement-time graph • acceleration-time graph • velocity-distance graph Essential Questions: • How do we translate from velocity-time graph to other graphs? • What are the information from a velocity-time graph can we get from the features of such a graph? A possible method to solve this question is to evaluate each graph with the features from the given graph. For example, for a acceleration-time graph, there must be a horizontal line at 0. Answer: D
5	Keywords • Flat golf course → falls back to the original height • Horizontal distance • Maximum height • Angle ➔ (thematic words indicating kinematics and projectile motion) Essential Questions • What are implicit info at the ‘max height’ and ‘when it returns to the original height’? • What kinematics equations are applicable?

	Answer: D
6	Keywords: • Total momentum • After collision Essential Questions: • Is total momentum conserved? Is there any net external force on the system? Answer: C
7	Keywords: • Free to move without friction Essential Questions: • What is the relationship between force, speed and time? • Does the gradient and/or the area under a F-t graph represent anything useful? • What is the gradient of speed–time graph? Answer: D
8	Keywords: • Range of minimum forces Essential Questions: • What are the forces acted on the block when it is completely submerge? • What are the forces acted on the block when it is completely lifted out of water? • When does minimum force occur? (→ lifted at constant velocity) Answer: D
9	Keywords: • Force from the slope on the skier Essential questions: 1. Draw the free body diagram of the skier 2. Draw the vector diagram of the forces in equilibrium Answer: B
10	Keywords: • Couple of torque M • Torque of couple Essential • How to determine the torque of a couple? Answer: C
11	Key info: - Constant speed - Level road - Efficiency is 16% - Travel 1 km - 1 kg of fuel provides 48 MJ of energy Essential questions: • How much energy is required from the fuel? • Which approach to use? Dynamics or Energy approach? (since information given in terms of energy efficiency, try energy approach) • What are the energy changes? What are the key words in the question that suggest what the energy supplied by the fuel is used for? Constant speed → no change in KE Level road → no change in GPE

	So energy from fuel goes to doing work against resistive forces. Answer: A
12	Key info: - Angular velocity, ω - earth Essential questions: • How is angular velocity related to period? (ω = $\frac{2\pi}{T}$) • How long does earth take to rotate about its axis? (24 hrs to be converted to sec) Answer: D
13	Key info: - Corner is an arc of a circle - Horizontal road - When road is wet, maximum frictional force is halved Essential Questions: • What provides the centripetal force? (frictional force) • How is the centripetal force related to linear speed? (F = $\frac{mv^2}{r}$) where m and r are constant Answer: D
14	Key info: - Point P is midway - From diagram, mass of earth is larger than mass of moon. Essential Question: • At point P, whose gravitational field will be stronger? • What is the direction of the resultant gravitational field? • How is gravitational potential at a point determined? • When is gravitational potential zero? Answer: C
15	Essential Questions: • How is orbital radius related to period? ($T^2 \alpha R^3$) Answer: C
16	Essential questions: 1. How does the PE change with position of the oscillating object? 2. How does the KE change with position of the oscillating object? 3. Can this change be represented as a mathematical formula to verify the answers to the above 2 questions? PE: The PE is maximum at the amplitude positions of the oscillations. KE: The KE is maximum at the equilibrium position of the oscillations. Formula for PE:

$E_P = \frac{1}{2} m\omega^2 x^2$ (upright parabola)
$E_K = \frac{1}{2} m\omega^2(x_0^2 - x^2)$ (inverted parabola)

Thus, equations verified the descriptions above.

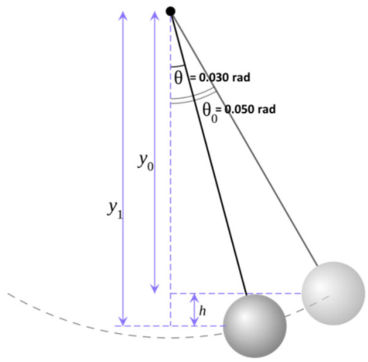
Answer: A

17

Answer: D

Essential questions:

1. *How is angular speed related to linear speed of the pendulum?*
2. *How can we find the speed of the pendulum at a specific angular displacement?*



Using conservation of energy,
TE at vertical height y_0 = TE at vertical height y_1
$GPE_{y0} = KE_{y1} + GPE_{y1}$
$KE_{y1} = GPE_{y0} - GPE_{y1}$
$\frac{1}{2} mv^2 = mgh$

$v = \sqrt{(2gh)}$
$= \sqrt{[2 \times 9.81 \times (1\cos(0.030) - 1\cos(0.050))]}$
$= 0.1257 \text{ m s}^{-1}$
since
$v = r\,\omega$
$\omega = v/r$
$= 0.1257/1.0$
$= 0.1257 \text{ rad s}^{-1}$

18

Answer: A
Essential question:
1. *What equation describes an ideal gas?*
2. *What are the constants in both situations?*

As the gas is ideal,
$P_1V_1 = n_1RT_1$ - - (eqn 1)
$P_2V_2 = n_2RT_2$ - - (eqn 2)
Dividing (1) by (2):

$(P_1V_1) / (P_2V_2) = (n_1RT_1) / (n_2RT_2)$

as the amount of gas is kept the same,

$(P_1V_1) / (P_2V_2) = (T_1) / (T_2)$

V_2
$= (T_2P_1V_1) / (P_2T_1)$
$= (600 \times 1.0 \times 10^5 \times 0.025) / (5.0 \times 10^5 \times 300)$
$= 0.010 \text{ m}^3$

19

Answer: B

Essential questions:
1. What is common for both processes? → same change in U (Why?)

Using 1st law of Thermodynamics,

Process PRQ:
$\Delta U_1 = W_1 + Q_1$

Process PSQ:
$\Delta U_2 = W_2 + Q_2$

Since both processes have the same resultant change,

$W_1 + Q_1 = W_2 + Q_2$

Q_2
$= W_1 + Q_1 – W_2$
$= (-3) + 8 – (-1)$
$= +6$ J

20 **Answer: D**

Essential questions:
1. What is the simplest way to calculate the mean KE of a molecule at sea level?
2. What are the properties at sea level?

At sea level, the temperature is about 20 °C, which is about 300 K.

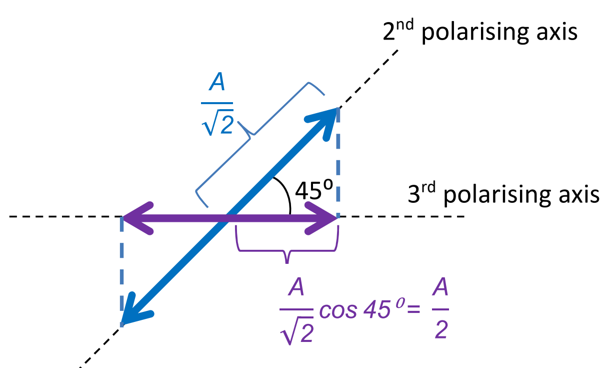
KE
$= 3/2\ kT$
$= 3/2\ (1.38 \times 10^{-23})\ (300)$
$= 6.2 \times 10^{-21}$ J

21 Keywords:
- Intensity I corresponding to amplitude A
- Polarization
- Relative angles between polarizing axes of the filters
- beam emerges from second filter with amplitude $\frac{A}{\sqrt{2}}$
- To find: **intensity** (not amplitude) of beam **after** passing the **third** filter

Essential Question:
- How are the amplitudes and intensities of the incident beam and emergent beam related?

The 'simple' answer if we ignore the first information that I and A are the intensity and amplitude of the **un**polarised light would be:

Vector resolution and recalling that Intensity α Amplitude^2 can be applied.



Since a beam of amplitude A corresponds to an intensity I,
and since Intensity α Amplitude^2,
therefore for the emergent beam with amplitude $\frac{A}{2}$, corresponding intensity would be $\frac{I}{4}$

Answer: ~~C~~ B [Note: CPDD highlighted that Examiners' Report is wrong. Correct answer is B not C. This is an unfair question for A-level as students are not expected to understand that after the first polarisor, while intensity is halved, amplitude stays the same.]

What it should be (Actual correct answer):

	Intensity	Amplitude
Unpolarised	I	A
After 1st filter	$\frac{I}{2}$ since only half the **energy** is transmitted	A Amplitude stays the same. Conceptual understanding of this is not really required at A-level.
After 2nd filter	To apply the relationship *Intensity α Amplitude*^{2} for **polarized** wave, Let $I_l = \frac{I}{2}$ (intensity after the 1st polarisor) $I_l \propto A^2$ Hence after the 2nd polarisor, an amplitude of $\frac{A}{\sqrt{2}}$ would correspond to an intensity of $\frac{I_1}{2} = \frac{\frac{I}{2}}{2} = \frac{I}{4}$ $\frac{I}{4}$	$A \cos 45° = \frac{A}{\sqrt{2}}$
After 3rd filter	an amplitude of $\frac{A}{2}$ would correspond to an intensity of $\frac{I_1}{4} = \frac{\frac{I}{2}}{4} = \frac{I}{8}$ $\frac{I}{8}$	$\frac{A}{\sqrt{2}} \cos 45° = \frac{A}{2}$

Answer: B

22 Keywords:
- stationary wave
- tuning force (→ single frequency of sound produced)
- tube with water and air (→ closed pipe)
- **processes** responsible for **formation** of stationary wave

Essential Questions:
- What are the conditions for a stationary wave to form?
  - ➔ two or more waves of the same type, frequency and speed,
  - ➔ travelling in opposite directions along the same line, and,
  - ➔ overlap repeatedly.
  - ➔ Additionally, if boundary conditions are present, these must be met. *[This is not really required in this question, but good to remember.]*
- How are these conditions met in this context?
  - ➔ When tuning form vibrated, it disturbs the air molecules, generating a sound wave
  - ➔ This sound wave travels down the tube, and is reflected off the water surface (closed end)
  - ➔ When the reflected wave reaches the open-end, it is again reflected (due to difference in acoustic impedance).
  - ➔ Process continues, with repeated reflections occurring at the closed and open ends.
  - ➔ The incident wave and reflected wave travel along the same line and continuously overlap, thus forming a stationary wave.
  - ➔ There are 2 boundary conditions in this case (displacement node at closed end and displacement antinode at open end). The fact that a stationary wave formed implies that the tuning fork produces sound wave of a wavelength that matches the resonant frequency of vibration of the air column (odd number multiple of a quarter of a

<table>
<tr><td></td><td>wavelength). [This is not really required in this question, but good to remember.]
• What are the processes involved?
➔ Interference (of the incident and reflected waves to produce a resultant wave according to the principle of superposition).
➔ Reflection is key in this context

Answer: D</td></tr>
<tr><td>23</td><td>Keywords:
• sound waves from the two loudspeakers combine

Essential Question
• What determines the shape of the resultant wave?

Principle of superposition is applied – the resultant displacement at each point is given by the vector sum of the displacements caused by the individual waves at that point.

Cannot be options A and B, since the resultant wave is no longer symmetrical about the turning points like in wave P.

Since the right side of the turning point in the resultant wave is higher than that in wave P, has to be option D not C.

Answer: D</td></tr>
<tr><td>24</td><td>Keywords:
• Two point charges
• charge Q
• separation r
• repel
• with a force F
• To find: the force between two charges, each of charge (Q + 2Q), separation is 3r

Essential Question:
• How is the force between two point charges related to charge and separation?

Apply Coulomb's Law.

For the point charges of charge Q and separation r,
$F = \frac{Q.Q}{4\pi\varepsilon_o r^2}$ ---------- (1)

For the point charges of charge 3Q and separation 3r,
Force = $\frac{3Q.3Q}{4\pi\varepsilon_o (3r)^2} = F$ (no difference from (1))

Answer: C</td></tr>
<tr><td>25</td><td>Keywords:
• Equal separation on the grid lines
• Position of Q
• Electric field strength 16.0 N C^{-1} and its position
• Electric field strength 32.0 N C^{-1} and its position

Essential Questions
• How does Electric field strength at a point due a Point charge varies with the distance from the charge?
• How do you calculate the distance at R and S from Q?

Answer: C</td></tr>
<tr><td>26</td><td>Keywords:
• Constant internal resistance (r)</td></tr>
</table>

- Variable resistance (R) gradually reduced
- Terminal p.d.
- Power wasted in internal resistance

Essential Questions

- Since emf E and r are constants, and R is varying, is the current I constant of varying?
- Can you express I in terms of E,r and R?
- Can you express terminal p.d. and power wasted in internal resistance in terms of E,r and R?

Answer: B

27 Keywords:

- Charge carriers are electrons
- Same cross-sectional area
- Number of free electrons per cubic metre in each material

Essential Questions

- What is equation for mean speed of electrons (drift speed)?

Answer: C

28 Keywords:

- Thermistor, LDR and fixed resistor connected in series
- Voltmeter placed across thermistor-LDR combination
- Resistance of thermistor decreases with temperature

Essential Questions

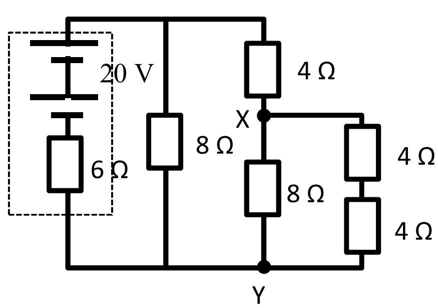
- Using potential divider principle, what is the expected ratio of the resistance of thermistor-LDR combination to the resistance of the fixed resistor, in order to get the smallest reading of voltmeter?

Answer: A

29 Key words:
Battery with internal resistance
Potential difference between junctions X and Y

Essential questions:

1. How to simplify the circuit (which is parallel or in series with which?)



There are many ways to solve this problem, one common method is to use potential divider method. But before this we will need to work out the effective resistance across XY.

Solve this from the furthest branch away from the cell.

R_{eff} across XY = 4 Ω
R_{eff} across the cell = 4 Ω
Hence p.d. across the 8 Ω resistor = p.d. across the cell = 4/(4+6) x 20 = 8 V
Therefore the p.d. across XY = ½ (8) = 4 V

	Answer: B

30 Key words:

- Metal disc rotates between the poles of magnet
- Electromagnetic force on a free electron

Essential question:

1) Why is there a force on the electron? *Because there is a moving charge in a magnetic field.*
2) How do we know the direction of force? *Use FLHR*
3) What do we need to take note of if it is a force on free electron? *Direction of electron is in the opposite direction of current in FLHR.*

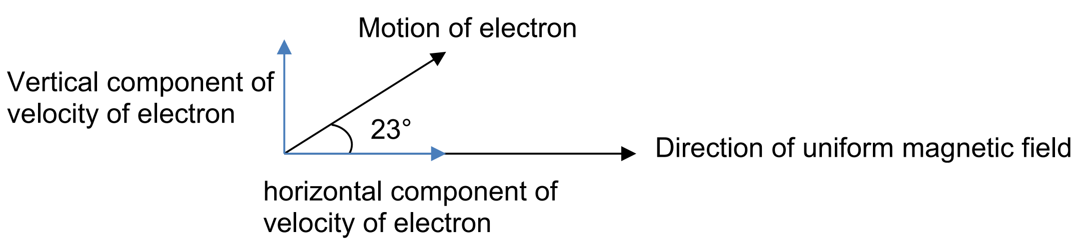
Answer: B

31 Key words:

- Force on electron moving in an uniform magnetic field

Essential questions:

1) How does the speed of electron relate to force and magnetic field strength? $F = Bqv \sin \theta$
2) How does the force relate to its motion?



There will only be a force affecting the vertical component of velocity but not the horizontal component as that velocity is parallel to the magnetic field.

A force which is perpendicular to both the velocity and magnetic field will cause a change in direction on the velocity but not its magnitude as it is perpendicular to it. This cause the electron to move a circular motion. At the same the time, the horizontal component of the electron will cause the electron to continue its horizontal motion in the direction of uniform magnetic field. Since there is no change in the magnitude of velocity, there is no change in the radius of the circle. The motion is therefore a helix instead of a spiral.

Using $F = Bqv \sin \theta$ where θ is 23°, $v = 1.4 \times 10^5$ m s^{-1}

Answer: A

32 Key words:

- One coil on top of the other with a different number of turns.
- Flux of one coil changes uniformly to zero

Essential question:

1) How does a change in flux in one coil produce p.d. in the other? *Faraday's law*
2) How does the number of turns affect the magnitude of p.d. across the coil? $\Phi = NBA\cos\theta$, e.m.f. induced = $- d\Phi/dt$

e.m.f. = (2000 x 0.34 – 0)/0.24 = 2800 V

Answer: C

33 Key words:

- Dimension of coil
- Number of turns of coil

	- Right-angles to magnetic field of uniform magnetic flux density Essential questions: 1) How do magnetic flux density, magnetic flux and magnetic flux linkage relate to one another? Φ = NBA, φ = BA, where A = $8 \times 10^{-2} \times 10 \times 10^{-2} = 8 \times 10^{-3}$ m^2 Hence B x 8×10^{-3} = φ (eliminate B and C) Φ = 800 x φ (Answer: D)
34	Key words: - Peak voltage of 180 V, average power dissipated Essential questions: 1) How does peak voltage relate to average power dissipated? Answer: B
35	Key words: - Particulate nature Answer: B
36	Key words: - 'Graph is plotted …. against transmission coefficient' Essential questions: 1) What is the equation that relates both coefficient? Linearise as according to the question. Answer: B
37	Keywords: • 'each having five … per atom', intrinsic semiconductor, absolute zero Answer: D
38	Keywords: • p-n junction • Movement of holes in forward biased operation and electrons in reverse biased operation. Essential Questions: • How do the majority charge carriers in both the p-type and n-type semiconductor flow during forward and reverse biased conditions? In reverse biased operation, electrons cross from n-type to p-type and set up the internal electric field. In forward biased operation the external electric field is able to allow the holes from the p-type to cross over the junction to the n-type semiconductor. Answer: C
39	Keywords: • Half life to be determined from the information of decay constant. • Remaining number of nuclei remaining is provided rather than the number that has decayed. Essential Questions: • Which equation is best suited to solve the question?

	$\lambda = 2.6 \times 10^{-8}$ s^{-1} $t_{1/2} = \frac{0.693}{\lambda} = 2.67\text{x}10^{7}$ s $N = N_0 e^{-\lambda t}$ $8.6 \text{ x } 10^{21} = 7.7 \text{ x } 10^{23}\ e^{-(2.67\text{x}10^{7})t}$ $\frac{8.6 \text{ x } 10^{21}}{7.7 \text{ x } 10^{23}} = e^{-(2.67\text{x}10^{7})t}$ $t = \frac{\ln\left(\frac{8.6 \text{ x } 10^{21}}{7.7 \text{ x } 10^{23}}\right)}{-2.67 \text{ x } 10^{7}}$ $= 1.7\text{x}10^{8}$ s Answer: C
40	Keywords: • Half-life and count-rate • Essential Questions: • What is the remaining number of radioactive nuclides present in the sample after one half-life? • What is the total number of radioactive nuclides present at any one time? Fact. Total number of nuclides is always a constant. This is equal to the initial number of radioactive nuclides present initially. For the time, *T*, the number of nuclides remaining and the daughter nuclide intersects exactly where the numbers are equal to each other. This can only be when one half life has passed. Answer: C

Paper 2

				Marks
1	**(a)**		The **ohm** is the SI unit of resistance. **One ohm** is the resistance of a conductor across which a potential difference of **one volt** produces a current of **one ampere**. **ER:** The majority of the answers did not provide a correct definition of the ohm. Many defined resistance or combined units and quantities.	**B1**
	(b)	**(i)**	Key Points: • Resistivity • Actual uncertainty/ies Solution ρ = RA/L = VA/IL = V(πd^2/4)/IL = (1.50)(π)(0.23 x 10^{-3})^2/4(0.32)(0.40) = 4.87 X 10^{-7} Ω m = 4.9 X 10^{-7} Ω m **<u>Examiner's Report:</u>** Some answers showed an area calculated by using the diameter or omitted powers of ten.	 **M1** **M1** **M1** **A1**

(ii)

- Key Points: Resistivity
- Actual uncertainty/ies

Solution

$\rho = V(\pi d^2/4)/IL$

$\Delta\rho/\rho = \Delta V/V + 2\Delta d/d + \Delta I/I + \Delta L/L$

$= 0.01/1.50 + 2(0.01/0.23) + 0.01/0.32 + 0.1/40.0$

$= 0.127$ **M1**

$\Delta\rho = 0.127\ \rho$

$= 0.127\ (4.87 \times 10^{-7})$ **A1**

$= 6.2 \times 10^{-8}$

$= 6 \times 10^{-8}\ \Omega$ m

Examiner's Report:

Most answers related an equation linking the fractional or percentage uncertainty in the resistivity to the corresponding uncertainties in the measured quantities. A minority subtracted uncertainties or did not double the percentage uncertainty for the radius or diameter to give the percentage uncertainty for the area. Other answers used the given uncertainty in the diameter when calculating the fractional or percentage uncertainty in the radius. A small minority of answers gave a correct calculation but rounded to too few significant figures on the answer line.

(iii)

Key Points:

- actual uncertainty round off to 1 s.f
- value round off to the same accuracy as the actual uncertainty

Solution

$\rho = 4.9 \times 10^{-7} \pm 0.6 \times 10^{-7} = (4.9 \pm 0.6) \times 10^{-7}\ \Omega$ m **A1**

Examiner's Report:

A significant number of answers gave the wrong number of significant figures, number of decimal places and powers of ten. A common error was to state the uncertainty to more than one significant figure.

(c)

Key words:

- accuracy
- precision

Essential questions:

1) What is the meaning of the above terms?
2) How to relate to the values calculated in (b)(iii)?

Accuracy: The calculated value of ρ obtained from measurements is within $\frac{(4.9 - 4.4)}{4.4}$ = 11% of the accepted value of ρ. **B1**

Precision: The calculated value of ρ obtained from repeated measurements is within $\frac{0.6}{4.9}$ = 12% of the mean value. **B1**

Examiner's Report

			*The majority of answers gave an explanation of the terms without making reference to answers in **(b)(iii)**. Most referred to the range of the readings, the number of significant figures or the actual uncertainty.*	

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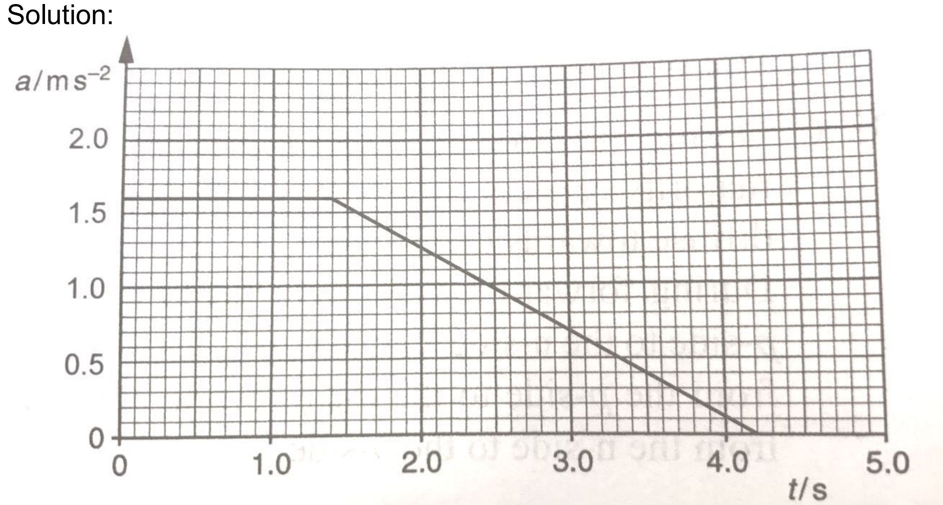
<tr><td></td><td></td><td></td><td></td><td>Marks</td></tr>
<tr><td>2</td><td>(a)</td><td></td><td>
Key words:
- Resultant force
- Object starts from rest

Essential questions:
1) At t = 0.7 s, what is the value of the net force as seen from the graph?
2) How is acceleration related to F_{net}?

Solution:
By Newton's 2nd law, F = ma
1.4 = 4 x a
a = 1.6 m s^{-2}
Examiner's Report:
A minority of answers gave the force from the graph as 6.2 N or 6.0 N. (Tip: need to read off graph accurately)
</td><td>

M1
A1</td></tr>
<tr><td></td><td>(b)</td><td></td><td>
Key words:
- On Fig. 2.2
- Show quantitatively (means to keep in mind the values and not just do a rough sketch)
- Include appropriate values (implies that further calculation may need to be done)

Essential questions:
1) Similar to part (a), what is the relationship between F_{net} and acc? How do we determine acc from an F – t graph?
2) What should be the shape of the graph?

Solution:


B1 – shape of graph
B1 – correct corresponding values of a and t on y and x axis respectively.

Examiner's Report:
This part was answered well.
</td><td></td></tr>
<tr><td></td><td>(c)</td><td></td><td>
Key words:
- Use Fig 2.1
</td><td></td></tr>
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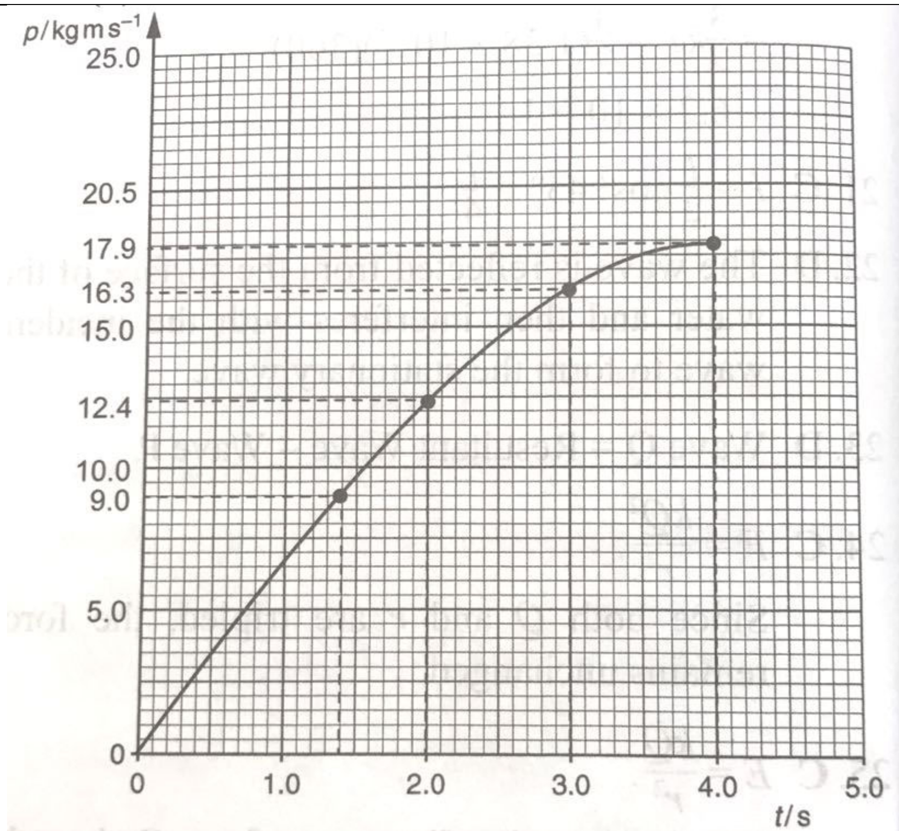
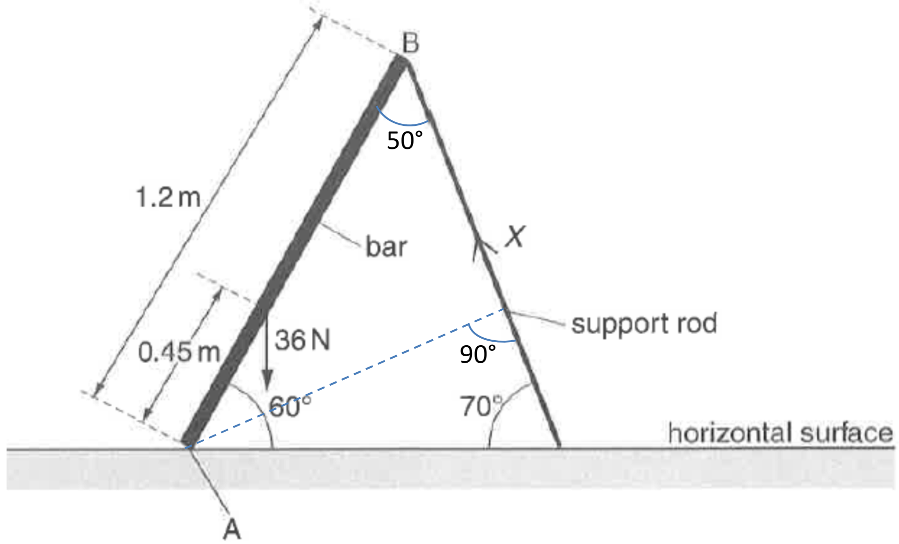
			- Impulse - From t = 0 to t = 1.4 s Essential questions: *1)* What is impulse? *2)* How is it represented on a F-t graph? (area under graph) Solution: Impulse = F.Δt = 6.4 (1.4) = 8.98 kg m s^{-1} *Examiner's Report:* Some answers gave an impulse calculated for the entire duration of the force. (Read the Q carefully! Impt to underline key phrases)	 **M1** **A1**
	(d)		Key words: - Show quantitatively - Momentum - From t = 0 to t = 4.2 s - Include values of p Essential Questions: 1) How is change in momentum determined from a F-t graph? (area under graph) 2) How does it vary with time? (that will determine whether the p-t graph is varying or constant) Solution: For t = 0 to t = 1.4 s, area of rectangle is 1.4 x 6.4 = 8.96 = 9 kg m s^{-1}(force is a constant value so graph of p-t should show a straight line) For t = 1.4 to t = 2 s, area of trapezium is 0.5 x 0.6 x (6.4+5) = 3.4 kg m s^{-1} (force is observed to decrease over time so gradient of p-t graph should be decreasing.) value of p at t = 2 s = 9 + 3.4= 12.4 kg m s^{-1} (3.4 is added to 9 as the change in momentum is still a positive one) For t = 2 s to t = 3 s, area of trapezium is 0.5 x 1 x (5+2.8) = 3.9 kg m s^{-1} value of p at t = 3 s = 12.4 + 3.9= 16.3 kg m s^{-1} (Force is observed to decrease over time so gradient of p-t graph should be decreasing.) For t = 3 s to t = 4.2 s, area of triangle is 0.5 x 2.8 x (1.2) = 1.68 kg m s^{-1} value of p at t = 4.2 s = 16.3 + 1.68 = 17.9 kg m s^{-1} (Force is observed to decrease over time so gradient of p-t graph should be decreasing.)	

			 **A1** – correct corresponding values of p and t **B1** – shape of graph **B1** – values of p are increasing *Examiner's report:* The majority of answers applied the previous answer in **(c)** correctly to the graph for the first 1.4 s. A minority of answers gave the correct graph for the time from 1.4 s to 4.2 s. A significant number of answers suggested the momentum decreased in this time although a force was still being applied (in the same direction. Therefore momentum should actually continue to increase with time). Some answers gave an unsuitable momentum scale for the *y*-axis. There was insufficient accuracy in the drawing of the latter stage of the graph.	

				Marks
3	**(a)**		Key words: - Non-uniform bar (weight does not act at the centre of the bar) - Use principle of moments Essential questions: *1)* What are all the forces acting on the bar? (good practice to isolate it by drawing the FBD and then show all forces acting on it) *2)* Where is the best position to take the pivot? *3)* What is the perpendicular distance of the weight to the pivot? (0.45 sin 30) *4)* What is the perpendicular distance of *X* to the pivot? (starting from pivot, draw a line that cuts the support rod perpendicularly)	



Solution:

Taking moments about A,
By principle of moments,
Total anticlockwise moments = total clockwise moments

M1

$36 \times 0.45 \sin 30 = X \times 1.2 \sin 50$

$X = 8.81$ N

A1

Examiner's Report:

A significant number were less successful with the moment due to force *X*, failing to **determine the perpendicular distance to the pivot.**

(b) **(i)** Key words:

- equilibrium

Essential questions:

1) What are the conditions necessary for an object to be in equilibrium? ($F_{net} = 0$ and Net moment about any point = 0)
2) What if no force acts at A? Will conditions for equilibrium be satisfied?

Solution:

The **support rod provides a leftward component of force** on the bar. However, **weight is a vertical force** acting downwards and hence **unable to balance the leftward force** due to support rod. Therefore, for the bar **to be in horizontal equilibrium** there **must be a rightward component of force provided by *F*** on the bar at point A. **B1**

Additionally, taking moments about B, both the weight and the rightward component of *F* produce anticlockwise moments about B. Thus ***F* must have a vertical component acting upwards to produce a clockwise moments about B to balance the anticlockwise moments.** **B1**

Examiner's Report:

There were a significant number of answers that did not relate to the situation in the question (You need to make ref to the given scenario!). The explanations often did not describe the conditions needed for equilibrium (usually equilibrium questions are like that – relate your answer to the conditions of eqm).

(ii) Key words:

- Magnitude of *F*

Essential questions:

1) Which conditions of equilibrium can I use?
2) How can I relate what I did in part (i) to my answer in part (ii)? (solve by considering forces)

Solution:

For horizontal equilibrium, Net horizontal force = 0 **M1**

∴ Horizontal component of $F = X \cos 70 = 8.8116 \cos 70 = 3.0137\ N$

For vertical equilibrium, Net vertical force = 0

∴ Vertical component of $F = 36 - X \sin 70 = 36 - 8.8116 \sin 70 = 27.7198\ N$

$| F | = \sqrt{3.0137^2 + 27.7198^2} = 28\ N$ **A1**

Examiner's Report:

A significant number of answers gave clear and concise solutions, either using Pythagoras' Theorem or using the cosine rule. Some answers did not determine the components of force *F* that would balance the resultant of the force *X* and the weight of the bar. A significant number of answers did not determine the correct angle to use with the cosine rule.

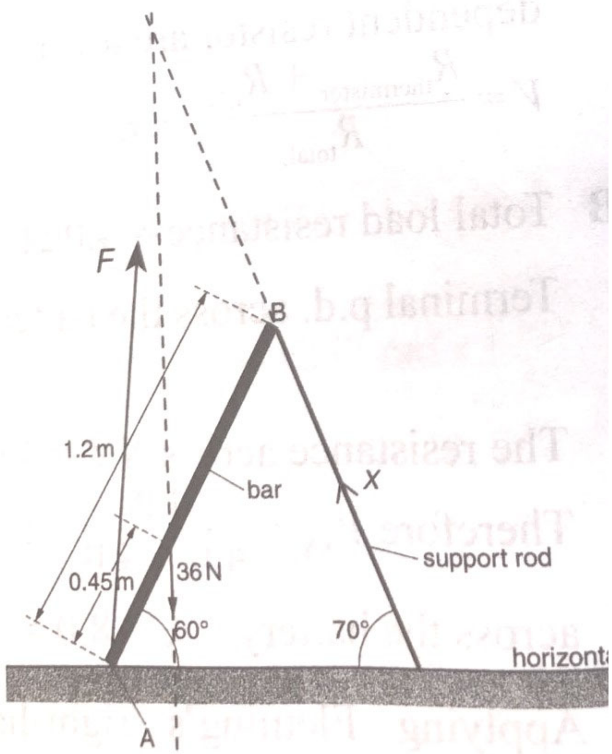
(iii) Key words:

- On Fig 3.1
- Arrow
- Approximate direction

Essential questions:

1) How to check for rotational equilibrium? (all the line of action of the forces must intersect at a common point.)

Solution: **B1**



			Examiner's Report: A majority of answers showed an arrow in the correct direction.	

				Marks
4	**(a)**		Key Words: • The small size of the nucleus compared to that of an atom Solution: 1. **Most** of the α-particles pass straight through undeflected. This suggests that the atom is **mostly** empty space with a nucleus that is very much smaller **compared to** the atom. 2. A very small **fraction** of the α-particles are deflected b by more than 90°. An even smaller **fraction** is deflected by 180°. This suggests that the probability of near head-on collisions is negligible due to the extremely small size of the nucleus **relative to** the atom. **<u>Examiner's Report:</u>** There were many answers that described one of the results as the majority of the α-particles having no or very little deflection. Some referred to a few α-particles being deflected through angles greater than 90° at the gold foil **without comparing** the few deflected with the large numbers of α- particles that are involved.	 **B1** **B1**
	(b)	**(i)**	Key Words: • Initial kinetic energy of 4.8MeV Solution: $$kinetic\ energy = \frac{1}{2}mv^2$$ $$4.8\ x\ 10^6(1.60\ x\ 10^{-19}) = \frac{1}{2}(4)(1.66\ x\ 10^{-27})v^2$$ $$v = 1.5\ x\ 10^7\ m\ s^{-1}$$ (Shown) **<u>Examiner's Report:</u>** The answers for this part were generally good. A few answers gave the mass of the α-particle as a value of 4u. A small minority of answers included the mass of two electrons for the α-particle.	 **M1** **M1**
		(ii)	Solution: The electric potential at a point in an electric field is defined as the work done per unit positive charge by an external agent in moving a point charge from infinity to that point (without any change in kinetic energy) **<u>Examiner's Report:</u>** A significant number of answers did not give an acceptable definition. A major error was the omission of the charge being positive.	 **B1**

		(iii)	Essential Question: • What happens to all the kinetic energy of the particle when it comes to rest at distance *d* from G? • Conservation of energy • Particle was initially at a very long distance away from gold nucleus Solution: $Gain\ in\ electric\ potential\ energy = Loss\ in\ kinetic\ energy$ $\frac{Qq}{4\pi\varepsilon_0 d} - 0 = \frac{1}{2}mv^2 - 0$ $\frac{79(1.60\ x\ 10^{-19})2(1.60\ x\ 10^{-19})}{4\pi(8.85\ x\ 10^{-12})d} = 4.8\ x\ 10^{6}(1.60\ x\ 10^{-19})$ $d = 4.7\ x\ 10^{-14}m$ **Examiner's Report:** A minority of answers determined the distance. The majority of answers used inappropriate equations. Commonly seen misconceptions were the use of $1/d^2$, the use of a single charge, the use of a charge of 4 for the alpha particle, the use of mass numbers and the omission of the factor of e^2 in the expression for the electrical potential energy.	 **M1** **M1** **A1**

				Marks
5	(a)		Keywords: • Sinusoidal AC voltage • Mean power • Maximum power (a) For **any** AC, $Mean\ Power = I_{rms}V_{rms}$ For **sinusoidal** AC, $I_{rms} = \frac{I_0}{\sqrt{2}}$ and $V_{rms} = \frac{V_0}{\sqrt{2}}$ Thus, $Mean\ Power = I_{rms}V_{rms} = \frac{I_0}{\sqrt{2}}\frac{V_0}{\sqrt{2}} = \frac{I_0V_0}{2} = \frac{1}{2}P_0 = \frac{1}{2}Max\ Power$ ***Be clear which equations apply to any AC and which apply to sinusoidal AC only.** **Examiner's Report** The majority of answers showed this correctly.	 **A1**
	(b)	(i)	Keywords: • Period of the sine graph, Fig. 5.1 From the graph, period , T = 18 ms $\omega = \frac{2\pi}{T} = \frac{2\pi}{18 \times 10^{-3}} = 349.1 = 350\ rad\ s^{-1}$ **Examiner's Report** The majority of answers gave the correct value. Other answers gave an	 **A1**

			incorrect unit or omitted it. The most frequent incorrectly given units were s^{-1}, rad, rad^{-1} and Hz. A significant minority of answers presented an error with the power of ten in the value given for the time.	
		(ii)	Keywords: • Peak voltage of the sine graph, Fig. 5.1 From the graph, peak voltage = 170 V $V_{rms}\, for\, V_1 = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120.2 = 120\, V$ **<u>Examiner's Report</u>** This majority of answers gave this correctly.	**A1**
	(c)		Keywords: • Period of the square graph, Fig. 5.2 Essential Questions • What are the steps to determine R.M.S. value from a graph? From Fig. 5.2, period = 18 ms Squaring the graph Fig. 5.2, $\langle {V_2}^2 \rangle = \frac{Area\ under\ the\ graph\ for\ 1\ period}{1\ period} = \frac{170^2 \times 90}{180} = \frac{170^2}{2}$ $V_{rms}\, for\, V_2 = \sqrt{\langle {V_2}^2 \rangle} = \frac{170}{\sqrt{2}} = 120.2 = 120\, V$ **<u>Examiner's Report</u>** A minority of answers gave a correct value for the r.m.s. voltage. The majority of answers did not average the squares of the voltages shown for one cycle. There were many answers that simply divided the maximum of 170 V by two.	**A1**
	(d)	**(i)**	**1.** The alternating current in the primary coil produces a time-varying magnetic field which is linked to the secondary coil by the soft iron core, creating a change in magnetic flux linkage with respect to time in the secondary coil and inducing an e.m.f. in it. According to Faraday's law of electromagnetic induction, the e.m.f. induced in the secondary coil is directly proportional to the rate of change of magnetic flux linkage through it. **<u>Examiner's Report</u>** The majority of answers did not refer to the actual location of the changes in magnetic flux. Answers often quoted Faraday's law without defining the symbols, and omitting the terms "flux linkage" and "rate of change" of flux linkage.	**B1** **B1**
			2. Essential Questions • What determines the magnitude of induced emf? How to apply Faraday's law? • What is common and what is different between the primary and	

				secondary coils? While the rate of change of flux is equal in magnitude for both the primary and secondary coils, since the number of turns in the secondary coil is less than in the primary coil, therefore the rate of change of magnetic flux linkage in the secondary coil is less than in the primary coil. Thus by Faraday's law, magnitude of the induced emf in the secondary coil is smaller than V_1. **<u>Examiner's Report</u>** It was not uncommon to observe responses that did not refer to Faraday's law and hence magnetic flux linkage as required in the question but instead used the equation Ns / Np = Vs / Vp . A significant number of answers gave the reason for the e.m.f. being less for the secondary coil as due to eddy current losses or heat losses in the 15 Ω resistor, even though the transformer was stated as being ideal and the secondary circuit was shown as an open circuit.	B1 B1
		(ii)		$V_{Srms} = \frac{N_2}{N_1} V_{1rms}$ $V_{Srms} = \frac{20}{500} \times 120 = 4.8\ V$ $I_{Srms} = \frac{4.8}{15} = 0.32\ A$ $I_{1rms} = \frac{N_2}{N_1} I_{Srms}$ $I_{1rms} = \frac{20}{500} \times 0.32 = 0.013\ A$ **<u>Examiner's Report</u>** The majority of answers gave the potential difference across the secondary coil. Most of these candidates went no further, stopping after calculating the value of the current in the secondary coil. Many answers did not distinguish between the primary, secondary, peak and r.m.s. aspects of the two circuits.	M1 A1

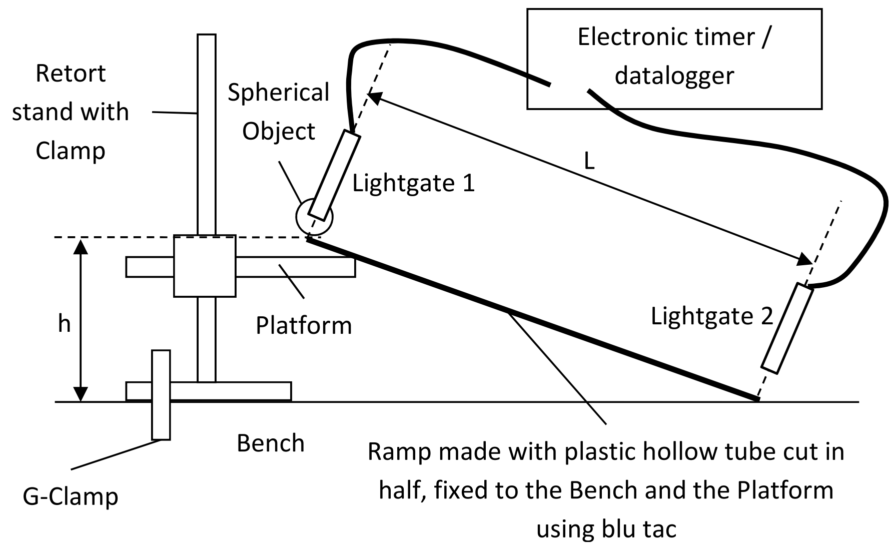
				Marks
6	**(a)**	**(i)**	Key words: - Refer to the graph and not anything else. The period increases at a decreasing rate with length. **<u>Examiner's Report:</u>** *The majority of answers did not give sufficient detail.*	 A1
		(ii)	Essential Question: • What does 'proportional' mean? How to relate this to a graph? T proportional to $\sqrt{M}$	

			→ (in equation representation) $T = k\sqrt{M}$ where k is a constant → (in graphical representation) From graph of T against M, obtain coordinates (*T, M*) from at least 2 points far apart enough. From each coordinate, calculate the ratio $\frac{T}{\sqrt{M}}$.. The calculated ratios should give the same constant value if *T* is indeed proportional to $\sqrt{M}$. For l = 0.25 m, choosing 3 points that are **far apart** on the graph (say M = 0.20 and 0.50), $\frac{0.78}{\sqrt{0.20}} = 1.7$ $\frac{1.23}{\sqrt{0.50}} = 1.7$ $\frac{1.10}{\sqrt{0.40}} = 1.7$ Similarly, For l = 0.50 m, $\frac{1.1}{\sqrt{0.20}} = 2.5$ $\frac{1.74}{\sqrt{0.50}} = 2.5$ $\frac{1.56}{\sqrt{0.40}} = 2.5$ For l = 0.75 m, $\frac{1.35}{\sqrt{0.20}} = 3.0$ $\frac{2.13}{\sqrt{0.50}} = 3.0$ $\frac{1.91}{\sqrt{0.40}} = 3.0$ For l = 1.00 m, $\frac{1.56}{\sqrt{0.20}} = 3.5$ $\frac{2.46}{\sqrt{0.50}} = 3.5$ $\frac{2.20}{\sqrt{0.40}} = 3.5$ Hence since ratio remains constant, T proportional to $\sqrt{M}$.	**M1** **A1**
		(iii)	Compare the ratio $\frac{T}{\sqrt{l}}$ at various points. For M = 0.20 kg, $\frac{0.78}{\sqrt{0.25}} = 1.6$ $\frac{1.1}{\sqrt{0.50}} = 1.6$ $\frac{1.35}{\sqrt{0.75}} = 1.6$ $\frac{1.56}{\sqrt{1.00}} = 1.6$ Hence since ratio remains constant, T proportional to $\sqrt{l}$	**B1**
			<u>**Examiner's Report:**</u> ***(ii)*** *and* ***(iii)*** *The majority of answers provided <u>three or more values</u> for the constant of proportionality. <u>Some answers were left as a fraction instead of being calculated to two significant figures.</u> Other answers did not give an equation that linked the two quantities given in each part question by a constant of proportionality. Some answers to* ***(iii)*** *did not utilise the idea that mass had to be kept constant when values of T and √l were compared.*	
	(b)	**(i)**	Fig. 6.3 shows the data for d = 1.20 mm Read off value of T for M = 0.40 kg and l = 0.50 m from Fig. 6.3: ➔ T = <u>1.56 s</u> Hence, lg T = lg 1.56 = <u>0.19</u> lg d = lg 0.00120 = <u>-2.92</u> <u>**Examiner's Report:**</u> *The majority of tables were completed correctly. There were a few errors made in the reading for T from the graph for the length and mass stated in the question.*	**B1**
		(ii)	1. Plot (-2.92, 0.19) on the graph, accurate to half the smallest division on the graph. 2. Draw the line-of-best-fit, following the three guidelines taught under Practical skills.	**B1** **B1**

			Examiner's Report: *The majority of points were plotted correctly. A significant number of best-fit lines were incorrectly drawn, with points distributed unevenly about the line. There were a number of best-fit lines where two lines had been drawn, with the lower section clearly bending through the points.*	
		(iii)	Choose 2 points **on the line-of-best-fit**, **separated by more than half the length of the line drawn**. Gradient = $\frac{-0.20-0.60}{-2.72-(-3.13)} = -\frac{0.80}{0.41} = -1.95$ **Examiner's Report:** *The majority of gradients were correctly calculated. There were some issues with subtracting negative numbers and reading the negative lg (T / s) and lg (d / m) values from the line. A number of calculations for the gradient were inverted.*	**M1** **A1**
	(c)	**(i)**	$T = Kd^n(Ml)^{1/2}$ where K, n and $(Ml)^{1/2}$ are constants; T and d are variables $lg\ (T) = n\ lg\ (d) + lg\ [K(Ml)^{1/2}]$ If lg (T) is plotted against lg (d), a straight line graph is expected, where n is the gradient and $lg\ [K(Ml)^{1/2}]$ is the vertical-intercept. Hence, value of n equals to the value of the gradient. Note: since command word is 'Explain' not 'State', the linearization and a brief explanation is required for marks to be awarded. **Examiner's Report:** *The majority of answers linearised the equation and linked the gradient to n. Some answers included an attempt to use natural logarithms.*	 **A1**
		(ii)	From (b)(iii), and since given that n is an integer, n = -2. **Examiner's Report:** *The majority of answers gave n as a real number. Some answers omitted the negative sign.*	 **B1**
	(d)		$lg\ [K(Ml)^{1/2}]$ = vertical-intercept Substituting (-3.13, 0.60), $lg\ [K(Ml)^{1/2}] = 0.60 - (-2)(-3.13) = -5.66$ $K\sqrt{(0.40)(0.50)} = 10^{-5.66}$ $K = 5 \times 10^{-6}$ SI units (1 sig. fig.) **Examiner's Report:** *A minority of answers gave a correct evaluation for K. A significant number of answers simply gave the derived SI base units for K. There were a number of calculation errors, mainly due to the mishandling of negative values in transposing the equation.*	 **M1** **A1**
	(e)	**(i)**	Essential Question: • What are the defining characteristics of a SHM? ➔ Acceleration directly proportional to displacement from the equilibrium position, and, they are always oppositely directed. • How to apply the above to this context? (net torque instead of the	

			usual net force; angular displacement instead of the usual linear displacement) ➔ Compare angular acceleration and angular displacement Measure **angular acceleration** $\left(\frac{d^2\theta}{dt^2}\right)$ at various **angular displacements** θ. **Examiner's Report:** *This was not well answered, with very few answers giving the measurements needed.*	**B1**
		(ii)	**Plot a graph of** $\left(\frac{d^2\theta}{dt^2}\right)$ **against** $\boldsymbol{\theta}$**.** If a **straight line** graph **passing through the origin** and with **negative gradient** is obtained, then the motion is simple harmonic $\left(\text{i.e. } \frac{d^2\theta}{dt^2} = -\omega^2\theta\right)$. **Examiner's Report:** *The majority of answers were an attempt to use the equation a = –ω² x without any explanation of how the measurements would be used.*	**B1**

				Marks
7			**Planning Question**	
			Identification of variables Part 1: vary d, keep h constant • Independent Variable: Diameter of spherical object, d • Dependent Variable: Average linear speed of spherical object down the ramp • Controlled Variables: - height of slope, h - length through which the sphere rolls down (to keep work done against resistive forces similar) - initial speed must be kept constant at zero. - material of sphere and of the slope (these affect the air resistance and friction) Part 2: vary h, keep d constant • Independent variable: Height of slope, h • Dependent Variable: Average linear speed of spherical object down the ramp • Controlled Variables: - Diameter of Spherical Object, d - length through which the sphere rolls down (to keep work done against resistive forces similar) - initial speed must be kept constant at zero. - material of sphere and of the slope (these affect the air resistance and friction) Procedure:	



1. Set up the apparatus as shown.
2. Clamp the platform firmly to the retort stand and fix the plastic tube ramp on the platform and at the bottom of the ramp with blue tac, such that height h remains constant for this part of the experiment.
3. Measure h vertically from the bench to the top of the ramp using a half-metre rule. Use a spirit level at the base of the ruler during the measurement to ensure that the half-metre rule is vertical. Record h reading.
4. Measure using a half-metre rule and record the length L along the ramp between the 2 lightgates. Set L to be about 30 cm. Keep L constant throughout experiment parts 1 and 2. [controlled variable]
5. Measure and record the diameter of one of the spherical object using a vernier calliper. Measure it at least three times at different positions of the object and take the average of the readings to obtain an average d.
6. Place the spherical object at the top of the ramp. Release it such that it rolls down the ramp from rest. This should trigger Lightgate 1 and start the timer.
7. After travelling a distance L, Lightgate 2 should be triggered and this will stop the timer. Record the timing.
8. Repeat step 6 and 7 two more times to obtain an average timing. Record the average time taken, t.
9. Calculate the average linear speed v of the object rolling down the slope,
   $v = \frac{L}{t}$

Part 1:

10. Repeat step 5 to 9 by changing d, using the different spherical objects provided. Repeat until at least 6 sets of measurements are obtained.
11. $v = Cd^x h^y$
    Taking lg on both sides,
    $\lg v = \lg C + x \lg d + y \lg h$
    Plot a straight line graph of lg v against lg d. Calculate the gradient and the value is equal to x, where the y-intercept is $\lg C + y \lg h$

Part 2:

12. Use one of the spherical object with diameter d measured as per step 5. The same spherical object will be used throughout part 2 of the experiment.
13. Repeat step 6 to 9 by adjusting the height at which the platform is

clamped to the retort stand, such that at least 6 sets of measurement are taken with various h. Every time when the height is adjusted, h is measured as per step 3.

14. With the equation in step 11,
Plot a straight line graph of lg v against lg h. Calculate the gradient and this gradient value is equal to y. The vertical-intercept is equal to ($\lg C + x\lg d$).

15. To determine C, determine the vertical-intercept in the graph of part 2 and equate to ($\lg C + x\lg d$) using the value of x found in part 1, and, using the constant value of d used in part 2.

Additional points

1. Clamp down the retort stand to prevent accidental toppling of set up.
2. Use a box to catch the free rolling spherical object after travelling on the ramp to prevent rolling object on the floor and cause a hazard.

Key words

Determine the values of C, x, y.

Essential questions

How many variables are required to be evaluated?
How many values can be calculated in a typical straight line graph? Is it enough for the task required?
How to measure average linear speed? What are the quantities required and how to we measure the quantities?
How to measure diameter of a spherical object? How do we measure height of slopes? What are the instruments required?

Suggested Mark Scheme

	Code	Mark
Labelled diagram of a workable procedure	A1	1
Labelled diagram of a workable circuit	A2	1
Define & Method in measuring the DV	DV	1
Define & Method in measuring the IV	IV1	1
Method in changing the IV	IV2	1
Analysis of results Three graphs to find C, x, y	AN1 AN2 AN3	1 1 1
Control variables (state + explain how)	C	1
Details to ensure reliability and accuracy	D	2
Safety precautions	SP	1
Total		Max 12

Examiner's report:

Design

The majority of diagrams lacked clarity and often had a missing horizontal line (Bench) hence the apparatus looked like a set of lines floating in mid-air. A sketch of a ramp, without any means of varying height was often seen with no evidence of the use of a clamp or support. The labeling of the apparatus was generally incomplete.

Many responses referred to dependent and independent variables, although it was often difficult to interpret the meaning of the term control in these answers. The variables that were to be kept constant were not always clearly stated.

Procedure

The majority of the answers named the correct apparatus to measure the diameter of the spherical objects. The majority described a correct method

			of determining the velocity. A significant number of answers did not specify which instrument should be used to measure the distance travelled or how the light gates could be used to measure the velocity directly. A significant number of answers did not mention the number of sets of readings that would be required for a reliable graph. **Analysis** A significant number of answers described a suitable graph for analysis but some did not provide sufficient details on how the unknowns could be determined from the graph. Many answers stated what the gradient should be but not the y-intercept. **Detail** The majority of answers did not give sufficient detail. There were some good attempts to improve the reliability of the experiment. These includes measures to ensure a consistent path for the object as it rolled down the slope and the idea of timing over a fixed length.	

Paper 3
Section A

				Marks
1	**(a)**		Key words: accelerated from rest through a potential difference Essential question: how does the electron gain speed? By conservation of energy, Gain in KE = loss in EPE $\frac{1}{2} mv^2 - 0 = eV$ $\frac{1}{2} (9.11 \times 10^{-31}) v^2 = (1.6 \times 10^{-19})(850)$ $v = 1.7 \times 10^7$ m s^{-1} **<u>Examiner's Report</u>** Most answers showed a clear and satisfactory derivation.	 **M1** **A0**
	(b)	**(i)**	Key words: - Constant force acts at right angle to the plates - Original direction of motion of electron is normal to the electric field Essential question: What is the motion of the electron? $F = ma$ $a = (4.0 \times 10^{-15}) / (9.11 \times 10^{-31})$ $s_x = u_x t$ $t = (5.1 \times 10^{-2}) / (1.7 \times 10^7)$ $v_y = u_y + at$ $= 0 + at = 1.3 \times 10^7$ m s^{-1} **<u>Examiner's Report:</u>** *The majority of answers showed a calculation of the time of travel between the plates and also the acceleration of the electron, before determining the*	 **M1** **M1** **A1**

			velocity. Some answers assumed that the acceleration would continue for a distance of 5.1 cm.	
		(ii)	v = $\sqrt{v_x{}^2 + v_y{}^2} = \sqrt{(1.7 \times 10^7)^2 + (1.3 \times 10^7)^2}$ = 2.1×10^7 m s^{-1} **<u>Examiner's Report:</u>** ***With few exceptions, the correct procedure was used for the calculation of the resultant velocity.***	**M1** **A1**

				Marks
2	**(a)**		Key words: - Difference between evaporation and boiling Evaporation can occur at any temperature while boiling must occur at a fixed temperature. Evaporation can only occur at the surface of the liquid while boiling occurs throughout the entire liquid. Evaporation occurs without any bubbling. Boiling is accompanied by the presence of bubbles. **<u>Examiner's Report:</u>** *Candidates were able to state one correct difference.*	**B1**
	(b)		Keywords: • Pressure • Change in volume • Work done Work Done by the gas, $W = p\Delta V$ since pressure is constant $W = (1.05 \times 10^5)(1.69)$ $W = 177450 \approx 1.77 \times 10^5$ J **<u>Examiner's Report:</u>** Most answers completed this calculation successfully.	**M1** **A1**
	(c)		Keywords • Specific latent heat of vaporization • Mol • Average increase • Internal energy • **A** molecule • Boiling Work done calculated in (b) was for 1.00 kg of water. Specific latent heat of vaporisation, $L_v = W + \Delta U$ $\Delta U = L_v - W$ $\Delta U = 2.30 \times 10^6 - 1.77 \times 10^5$ $\Delta U = 2.123 \times 10^6$ J kg^{-1}	

			Number of molecules in 1 kg = (1.00 / 0.018 x 6.02 x 10^{23}) = 3.34 x 10^{25} Therefore, the average increase per water molecule is, $\Delta U_1 = \dfrac{2.123\times10^{6}}{3.34\times10^{25}}$ $\Delta U_1 = 6.35\times10^{-20}\,J$ **<u>Examiner's Report:</u>** Most answers correctly showed the total change in internal energy. It was common to find that, when calculating the increase per molecule, that either no allowance was made for the number of moles or that the Avogadro constant was omitted.	**M1** **M1** **A1**

				Marks
3	**(a)**		Keywords: • Circuit diagram, Fig. 3.1 Combined resistance of X and Y = $\left(\frac{1}{2.0}+\frac{1}{3.0}\right)^{-1} = 1.2\ \Omega$ Total resistance = 1.2 + 1.8 = 3.0 Ω Current in the cell = $\frac{EMF}{Total\ resistance} = \frac{1.5}{3.0} = 0.50\ A$ **<u>Examiner's Report</u>** This derivation was completed with few errors.	**M1** **M1** **A1**
	(b)		Keywords: • Power transfer Essential Questions • How to interpret the power transfer to the two external resistors? • What is the meaning of power transfer in the cell? (→ Rate of energy converted from other form to electrical form per unit charge driven round the complete circuit, or, power supplied by the cell to the circuit. It is NOT the power dissipated by the internal resistance of the cell!) Since the same current flows through the combined resistance of X and Y and the cell, $$Ratio = \frac{I^2R_{external}}{I^2(r+R_{external})} = \frac{R_{external}}{(r+R_{external})} = \frac{1.2}{(1.8+1.2)} = 0.4$$ **<u>Examiner's Report</u>** It was common to find that the power transfer in the internal resistance was calculated.	**M1** **M1** **A1**
	(c)		new effective external resistance = $\left(\frac{1}{4.5}+\frac{1}{3.0}\right)^{-1} = 1.8\ \Omega$ This is equal to the internal resistance of the cell. Since the current through the internal resistance and the effective external	**B1** **B1**

			resistance are equal, this implies half of the total power delivered by the cell would be dissipated in the external resistance, thus the ratio increases to 0.5. **Examiner's Report** Most answers stated that the combined resistance of the parallel combination would increase. Fewer answers went on to make statements justifying an increase or decrease in the ratio of the powers.	

				Marks
4	(a)		**Essential questions:** *1.* What determines the path of motion of a charged particle in a magnetic field? **Solution** Since the particle enters in a direction perpendicular to the field, the magnetic force is **always perpendicular to the velocity of the particle**. Thus, this force provides for the centripetal force on the particle, causing the velocity to **change its direction though not its magnitude**. Additionally, as the magnitude of the force is proportional to that of the magnitude of the particle's speed and its speed remains constant, this **force will not change in magnitude. This will result in a circular path with a constant radius**. *ER:* *There were some comprehensive answers; other answers were less than satisfactory. While answers often described the initial force as acting 'upwards' or in a direction normal to the initial path, they did not make it clear that the force would always be normal to the velocity of the particle.*	**B1** **B1** **B1**
	(b)	(i)	**Essential questions** *1.* What are the forces acting on the particle in a combined magnetic-electric field? *2.* What does it mean for the particle to not be deviated in its path? *3.* Can we assume the gravitational force on the particle to be negligible? **Solution** As the particle is not deflected, the net force on the particle in zero. Therefore, magnetic force F_B balances the electric force F_E $F_B = F_E$ $Bqv = qE$ $E = Bv$ $= (3.2 \times 10^{-3})(4.7 \times 10^{5})$ $= 1.5 \times 10^{3}$ V m^{-1}	**M1** **A1**
		(ii)	**Essential questions** *1.* How would the initial speed of the proton affect its motion? *2.* How would the magnitude of the forces change consequently? *3.* How is the orientation of the fields affect the consequent motion?	**B1** **B1**

			Solution By increasing the initial speed of the proton, the **magnetic force will increase its magnitude** while **electric force remains unchanged**. Hence **there will be a net force <u>directed upwards</u>**. As such, **the proton will <u>deflect upwards</u>**.	

				Marks
5			An intrinsic semiconductor has a small energy difference (about 1 eV) between the bottom of the conduction band and the top of the valence band. When temperature rises, more electrons in the valence band are thermally excited into the conduction band, leaving behind holes in the valence band. Both electrons in the conduction band and holes in the valence band contribute to electrical conduction. Thus when temperature rises, mobile charge carrier density in the semiconductor increases, hence reducing the resistivity. Although there is increased frequency of collisions between the mobile charge carriers and immobile atom cores of the semiconductor which tends to increase resistivity, the effect of the increase in mobile charge carrier density outweighs this second effect. **<u>Examiner's Report:</u>** *There were few comprehensive answers to this question. Many answers unnecessarily described the initial situation, as already outlined in the stem of the question. Many answers referred to the electron/hole pairs as 'conducting electricity'.*	**B1** **B1** **B1** **B1** **B1**

				Marks
6	**(a)**	**(i)**	Key words: - Determine half-life - Beta emission - Sulfur-32 is stable - Average count rate Essential question: What is the 'method' used to determine the half-life in this experiment? (→ Geiger-Muller tube connected to counter/ratemeter, exposed to the sample of Phosphorous-32. Record R and plot graph. Determine half-life from graph as will be done in the later part of the question.) Suggested answer: If the product is not stable, the average count rate measured will also include **additional count rate** by the activity of the product and hence the half-life of phosphorus-32 determined will not be accurate. *Examiner's Report:* *Answer based on the increase in the count rate were not common. Many answers referred simply to the count rate changing. Other answers referred to chemical reactions.*	**A1**
		(ii)	Key words:	

- Did not need
- Background radiation

Essential question: Why doesn't one need to account for background radiation in an experiment? – the effect is negligible

Suggested answer:
The background count rate is **very low** (usually less than 1 count per second) **as compared to the count rate from phosphorus-32** (counts are in hundreds per second, **about 1000 times** of the background count rate), hence the **percentage error of excluding the background count rate is negligible**.

B1

B1

Examiner's Report:
Few answers referred to the magnitude of background rate compared with the magnitude of the count from the source.

(b)

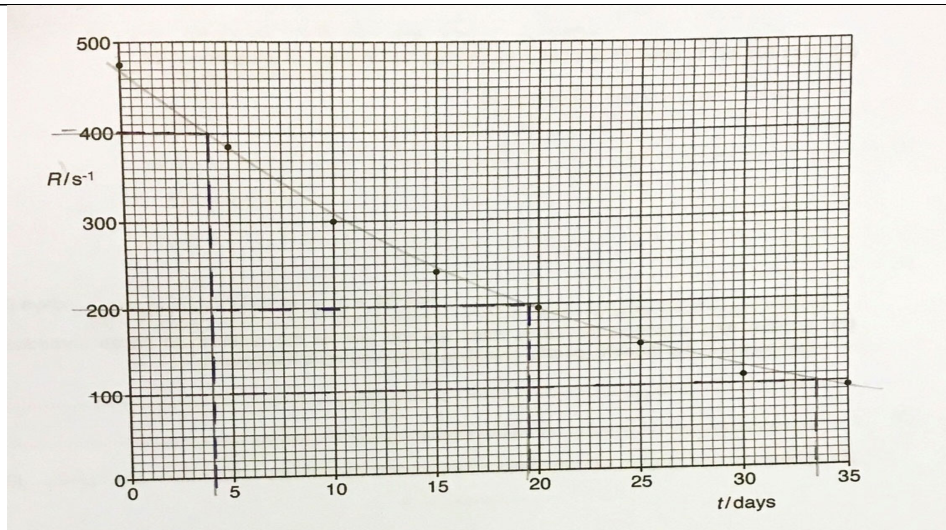


Fig. 6.1

Sketch the **best-fit curve**.

Using fig 6.1, when R = 400 s^{-1}, after one half-life, R will be reduced by half, i.e. R = 200 s^{-1}.
Time difference = $t_{1/2,\,1}$ = 19.5 – 4 days = 15.5 days **B1**

Since we are using a graph, we should find one more half-life and then find the average:

Indicate the time difference between R = 200 s^{-1} and R = 100 s^{-1},
Time difference = $t_{1/2,\,2}$ = 33.5 – 19.5 = 14 days **B1**

Hence $\langle t_{1/2} \rangle$ = (15.5 + 14)/2 = 14.75 = 15 days **A1**

Examiner's Report:
*Only a few answers used **multiple determinations of half-life** from a **drawn best-fit curve** in the calculation.*

	(c)		Key words: - Immediate symptoms (time related) - Careful shielding (dangerous!) Essential question: What would be a long term health hazard that is caused by the exposure of the source? Suggested answer: Although the count rates are too low, the student will still be exposed to the source for more than a month (at least 35 days, as seen from Fig 6.1) (if without careful shielding). Beta-particles can penetrate the skin and cause structural damage / mutate the DNA over a period of time, which may lead to longer term medical illness such as cancer. ***Examiner's Report:*** ***Answers stating that the radiation would accumulate in the body were common, as were answers that stated simply that the radiation presented a "health hazard".***	 **B1** **B1**

Section B

				Marks
7	**(a)**	**(i) 1.**	Solution: Displacement is the distance of the mass in a specific direction from its equilibrium position	 **B1**
		(i) 2.	Solution: Amplitude is the maximum displacement of the mass from its equilibrium position in either directions. **<u>Examiner's Report:</u>** In general, the meanings of *displacement* and *amplitude* were given correctly. A few answers defined *displacement* in terms of 'distance', and not 'distance moved'.	 **B1**
		(ii)	Solution: Simple harmonic motion is an oscillatory motion in which that body's acceleration is directly proportional to its displacement from its fixed equilibrium position and is always in opposite direction to this displacement. **<u>Examiner's Report:</u>** A number of answers referred to the equilibrium position.	 **B1** **B1**
	(b)		Key Words: • Restoring force Essential Questions: • What are the restoring forces in each scenario that give rise to the oscillations?	

			• Draw out the free-body diagrams for each scenario Solution: For the simple pendulum, the restoring force is **the component of the bob's weight that is tangential to the circular arc of its path**. For the floating block, the restoring force is the **difference** between the **upthrust exerted by the water on the block and the weight of the block of wood**. **<u>Examiner's Report:</u>** When describing the restoring force for the pendulum many merely referred to either the weight of the bob without considering components or to energy changes. For the floating block, most answers stated that the restoring force would be either the weight or the upthrust, depending on the depth of immersion of the block.	**B2** **B2**
	(c)		Key words: - fig 7.3 - depressed by a distance - part of the strip is compressed/extended Essential questions: How the structured of the strip deformed as shown in fig 7.3? What is the change in the length of the inner and outer surface Solution As the strip is bent, the length of the centre line is unchanged. The bending pulls atoms in the upper half of the strip further apart than their equilibrium separation and thus total length of the upper part is longer than the original length (i.e. extended). In the lower half, atoms are pushed closer than their equilibrium separation and thus total length of the lower part is shorter than the original length (i.e. compressed). ***Examiner's Report:*** Many answers attributed the compression to the clamp and the extension to the mass.	**B1** **B1** **B1**
	(d)		Key words: - displacement from the equilibrium point - C is a constant of the strip E is a constant for the material of the strip - Simple harmonic motion Essential questions: 3) What is the relation between a and x in a s.h.m.? Solution According to the equation C,E, L and M are constants So a is directly proportional to x Also, the negative sign indicates that a is always oppositely directed to x.	**A1** **A1**

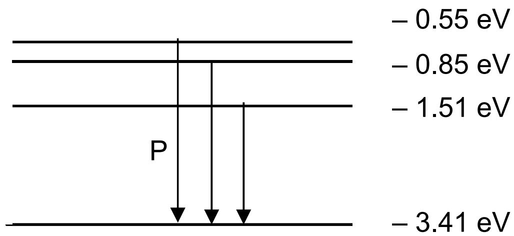
			Hence the motion is s.h.m. *Examiner's Report:* This was generally answered well..	
	(e)	**(i)**	Key words: - depression d Essential questions: 3) how does d related to x? 4) how to determine the period of the oscillation? Solution Time for 5 cycles = 1.05 s Period T = 1.05/5 s $\omega = 2\pi / T = 2\pi / (1.05/5) = 30$ rad s^{-1} *Examiner's Report:* This was completed successfully.	 **M1** **A1**
		(ii)	Key words: - without unit Essential questions: 1) how does the equation in (d) compared to the general equation of a s.h.m. $a = -\omega^2 x$? *Compare* $a = -(CE/L^3M)\,x$ *with* $a = -\omega^2 x$ $\omega^2 = (CE/L^3M)$ $C = \omega^2 L^3M / E$ $= 30^2 \times (0.8)^3 \times 0.150 / 2.0 \times 10^{11}$ $= 3.46 \times {}^{-10} = 3.5 \times 10^{-10}$ *Examiner's Report:* *Most candidates obtained the correct answer.* The major error was with powers of ten.	 **M1** **A1**
	(f)		Key words: - thy have the same frequency of oscillation Essential questions: 1) What is the relation between frequency and angular frequency? Solution Since $\omega = 2\pi f$ Given that they have the same frequency Both strips have the same angular frequency $\omega = 30$ rad s^{-1} Given that both strips have the same values of C = 3.5×10^{-10} & L =0.8 m From $\omega^2 = (CE/L^3M)$ $E_s/M_s = E_A/M_A$ $20/0.15 = 7.1 / M_A$ $M_A = 0.053$ kg	 **M1** **M1** **A1**

			Examiner's Report: A successful calculation was seen in many answers. Very few answers used proportionality in their calculation; most used a full substitution into the given constant.	

				Marks
8	**(a)**		A photon is a **quantum** of **electromagnetic radiation energy**. (Its energy equals to the product of the Planck constant and the frequency of the electromagnetic radiation.) **<u>Examiner's Report</u>** Most scripts described the photon as a 'packet' of energy but it was not always made clear that this energy is associated with electromagnetic radiation.	**B1** **B1**
	(b)	**(i)**	Key Words: Appearance Visible Emission line spectrum Solution: **Bright <u>coloured</u> <u>discrete</u> lines** are seen against a **dark background**. Towards the **violet end** of the spectrum (shorter wavelength) lines are **increasingly more closely spaced**. **<u>Examiner's Report:</u>** Most candidates gave satisfactory descriptions	
		(ii)	Key Words: Concept of Photon Discrete energy levels Solution: For each emitted photon, the energy is equal to the difference between the **electron** energy levels across which de-excitation takes place. The line spectra only show photons of certain allowed energies and this proves that the energy levels in an atom can only possess discrete and not continuous values. **<u>Examiner's Report:</u>** Many answers referred to energy levels in atoms, without any consideration of **electron** energy levels.	 **B1** **B1**
	(c)	**(i)**	Key words: - Emission in visible light spectrum Essential questions: 1) What is the range of energies of photons in the visible light spectrum? 2) What are the energies of the photons due to the transitions between the higher energy levels and – 13.6 eV.	

			Using the equation $E = hf$ $= h\frac{c}{\lambda}$ $= [6.63 \times 10^{-34}]\frac{3.0 \times 10^{8}}{400 \times 10^{-9}}$ $= 4.97 \times 10^{-19}$ J = 3.10 eV is the energy of a photon of **violet** light whose wavelength is 400 nm. This means energies of **visible** light photons of other wavelengths are **less than** 3.10 eV. Consider the **minimum** energy of photons from electron transitions that end at the – 13.6 eV level: Energy of photon transiting **from – 3.14 eV to –13.6 eV** = – 3.41 – (– 13.6) = 10.2 eV This means that photons resulting from transitions that end at the – 13.6 eV energy level have energies **equal or greater than** 10.2 eV. This **exceeds** the energies of the photons of the visible light spectrum. Hence none of the electron transitions that end at the – 13.6 eV level will result in emission in the visible light spectrum. ***Examiner's Report:*** *A correct calculation for energy of the photon in eV was seen in most answers. There was some confusion as to how to relate this energy to the energy changes shown in Fig. 8.1.*	B1 B1 B1 B1
	(c)	**(ii)**	**1.** Key words: - Visible spectrum Essential questions: - Which electron transitions would result in the visible spectrum (Balmer series)? → Tip: Emission/Absorption line spectra photons from isolated atoms e.g. hydrogen atoms, come from UV / Visible /IR ranges. UV has highest energy, followed by Visible then IR. → So far we know that **transitions ending at – 13.6 eV are too high in energy, in the UV range**. → Likely that **transitions ending at – 3.41 eV** will produce photons in the **Visible** range. The transitions that result in the visible spectrum will start from the higher energy levels and end at the – 3.41 eV energy level. Starting from the highest energy level as provided in the diagram of – 0.55 eV to – 3.41 eV, there are four possible energy levels to do the transition. - 0.55 eV – (- 3.41 eV) = 2.86 eV - 0.85 eV – (- 3.41 eV) = 2.56 eV - 1.51 eV – (- 3.41 eV) = 1.9 eV	

Since all these energy transitions are greater than 1.6 eV, all these will produce visible light photons.



Number of transitions that lie in the visible spectrum = 3.

A1

2. Key words:

- **Shortest wavelength** implies **largest energy** of photon.

Largest photon energy, E_{Max} = Largest loss of electron excitation energy, ΔE_{Max}

$$= (-0.55) - (-3.41 \text{ eV})$$
$$= 2.86 \text{ eV}$$
$$= 4.58 \times 10^{-19} \text{ J}$$

M1

Corresponding shortest wavelength of photon = $\dfrac{hc}{E_{Max}}$

$$= \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{4.58 \times 10^{-19}}$$
$$= 4.34 \times 10^{-7} \text{ m}$$

A1

Examiner's Report:
Commonly seen incorrect answers for the number of lines were 4 and 7.

(d) **(i)** Key words:

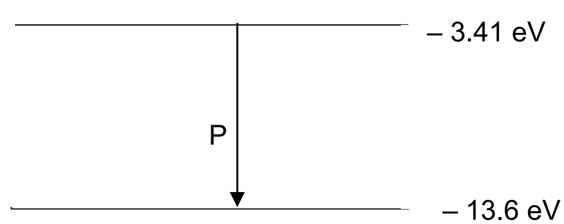
- Longest wavelength

Essential questions:

1) When does photoelectric effect occur?
2) Which transition will provide with the longest wavelength?

In the photoelectric effect the emission of electrons will only occur when the incident photon's energy is **at least** equal to (equal or larger than) the work function energy. In this case a photon of **at least** 5.6 eV is required. (From calculations in c(ii)2, visible light photons have lower energies. Hence must be from the ultraviolet light photons, i.e. transitions ending at – 13.6 eV.)

Hence the electron transition that will result in radiation with the longest wavelength to cause photoelectric effect is that from the smallest energy transition, i.e. between energy levels – 13.6 eV and – 3.41 eV.



B1

			Examiner's Report: This was usually answered correctly**.**	
		(ii)	Key words: - Maximum energy Essential questions: 1) What type of energy is in question? ➔ Max KE of the ejected electrons Using Einstein's photoelectric effect equation, $E_{photon} = \Phi + KE_{max}$ $(-3.41\ eV) - (-13.6\ eV) = 5.6\ eV + KE_{max}$ $10.19\ eV = 5.6\ eV + KE_{max}$ $KE_{max} = 4.59\ eV$ *Examiner's Report:* *Only some answers used the photoelectric equation to determine the correct answer.*	 **B1** **A1**
	(e)	**(i)**	Key words: - Photon - Free space Essential questions: 1) What is the speed of photon in free space? Time taken to travel the distance = $\dfrac{2.6 \times 10^{-10}}{3.0 \times 10^{8}}$ $= 8.7 \times 10^{-19}$ s ***Examiner's Report:*** *With few exceptions, this time was calculated correctly.*	 **B1** **A1**
		(ii)	Key words: - Maximum uncertainty in time - to cross a *<u>gold atom</u>* - reference to answer in (i), which was for *<u>free space, and across a distance equal to diameter of the gold atom</u>* Essential questions: 1) How to link the required uncertainty to the answer in (i)? → Atom is **<u>mostly</u> free space**, so the answer in (i) can give a good estimate for the context of an atom. 2) What is the distance a photon has to travel across a gold atom? → maximum distance would be the diameter; but if the photon passes through in other directions, it would travel less than diameter of atom, hence take lesser time than what was calculated in (i). So maximum uncertainty in time taken to cross a gold atom can be estimated to be the time calculated in (i). The **maximum** distance that a photon would need to travel through an atom would be the **diameter** of the atom.	

			But if the photon passes through **in other directions**, it would travel distances **less than the diameter**, hence **take lesser time than in (i)**. So **maximum uncertainty in the time taken to cross a gold atom can be estimated to be the time calculated in (i) itself, i.e. 8.7 x 10^{-19} s.** *Query by student: If there is an uncertainty of 8.7x10^{-19} m it means that there's a possibility of the value of time being zero which is not possible...?* ➔ *Why not? If it passes tangentially off the 'circumference' of the atom?* ➔ *For 'uncertainty' remember it is always $\pm$ __ a range, which means in a set of readings, some could differ from the true value with zero difference* ***Examiner's Report:*** *Only a small minority answered this correctly.*	**A1**
		(iii)	Key words: - photon Essential questions: 1. Which equation can be used to determine the uncertainty in the time of photon? Using the modified expression of the uncertainty principal $\Delta E \Delta t \geq \frac{h}{4\pi}$ Therefore $\Delta E \geq \frac{\frac{h}{4\pi}}{\Delta t} = 6.1 \times 10^{-17}$ J Since the uncertainty in the energy of the photon when crossing the atom is significantly (100 times) larger than the energy of the photon itself in free space, the energy of the photon may not be equal to that in free space. ***Examiner's Report:*** *Most answers quoted an equation for uncertainty.*	**B1** **B1**

				Marks
9	**(a)**	**(i)**	Key words: - Gravitational field strength g_P - At point P (due to M) Essential questions: 1. What is the formula for grav field strength at a point? 2. What is the direction of grav field strength? 3. Where is the starting point? (at centre of M) Suggested answer: $-\frac{GM}{x^2}$ Note: negative sign indicates that the direction of g_P is opposite to x which starts from centre of M.	**B1**
		(ii)	Keywords: - Potential energy Ep - Of small ball	

- At point P

Essential question:

1. What is the formula for grav potential energy?
2. Where is grav potential energy max? (at infinity and its value is 0)

Suggested answer:

$-\dfrac{GMm}{x}$ **B1**

Note: negative sign indicates negative work done by external agent in bringing mass m from infinity to point P without change in KE

(b) (i) Key words: gravitational field strength at the surface of the sphere is g_s.

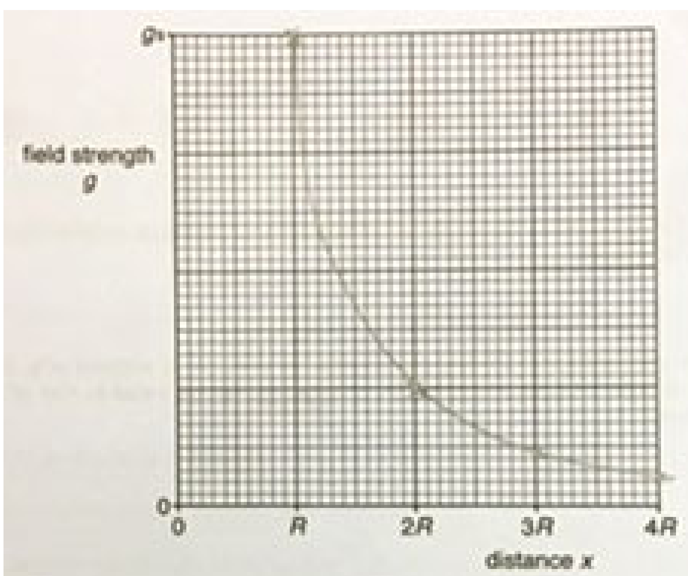
Essential question: How does gravitational field strength relate to distance?

Suggested answer:

Since a graph grid is given, and there are labels of R, 2R, 3R and 4R on the axes, it is expected that you will sketch a relatively accurate graph.

Since $g \propto 1/x^2$

Since x is the distance from the centre of the mass M,
at $x = R$, $g = g_s$.
At $x = 2R$, $g = \frac{1}{4} g_s$
At $x = 3R$, $g = 1/9\ g_s$
At $x = 4R$, $g = 1/16\ g_s$



Marking point [1 mark each]

- *Correct start point*
- *Correct shape*
- *Passing through appropriate points*

Examiner's report:
Well-drawn curves, passing through the appropriate points were in a minority. Some did not show the correct field strength.

		(ii)	Key words: - State and explain - Graph - Mass is lost uniformly Essential questions: - How would g change in relation to x? - How would the shape of the graph be affected? Suggested answer: Since g is directly proportional to mass of the sphere, a decrease in mass will cause the magnitude of g to be smaller at all values of x, including at the surface. Hence a similar graph but always lower than the original graph will be obtained instead. Since mass is lost from the surface, radius of the surface is decreased and thus the graph should start from x < R. ***Examiner's Report*** ***Many answers confused the change in mass with a change in distance from the centre of the spheres.***	**B1** **B1**
	(c)	**(i)**	Key words: - Centripetal force Essential questions: *1)* What is the force that provides the centripetal force on the two masses? By Newton's third law, the gravitational force that acts between star A and star B are equal and opposite in direction to each other. As the gravitational force on star A provides the centripetal force on star B and vice versa, the centripetal force on the two stars will be equal in magnitude.	**B1** **B1**
		(ii)	Key words: - Angular speed ω Essential questions: 1) What is the relationship between period and angular speed? $$\omega = \frac{2\pi}{T} = \frac{2\pi}{4.0 \times 365 \times 24 \times 3600}$$ $$= 4.98 \times 10^{-8}\ s$$ ***Examiner's Report:*** *Nearly all answers showed a successfully completed calculation.*	**M1** **A1**
		(iii)	**Essential question:** *1.* Which force provides for the centripetal force? **Solution** The gravitational force between the stars provides for the centripetal force. $F_{GA} = F_{CA}$	**M1**

			$(GM_AM_B)/d^2 = M_Ar_A\omega^2$ - - - (1) and $F_{GB} = F_{CB}$ $(GM_AM_B)/d^2 = M_Br_B\omega^2$ - - - (2) (1) / (2): $(M_A / M_B)(r_A / r_B) = 1$ $r_A = (r_B)(M_B / M_A) = r_B/3$ Since $r_A + r_B = d$ $r_A = d/4 = (3.0 \times 10^{11})/4 = 7.5 \times 10^{10}$ m ER: Some answers did not equate the centripetal forces or recognise that the angular speed is the same for both stars.	 **M1** **M1** **A1**
	(d)		**Solution:** From eqn (1) in c(iii): $(GM_AM_B)/d^2 = M_Ar_A\omega^2$ $(GM_B)/d^2 = r_A\omega^2$ M_B $= (d^2r_A\omega^2)/G$ $= [(3.0 \times 10^{11})^2(7.5 \times 10^{10})(4.98 \times 10^{-8})^2]/(6.67 \times 10^{-11})$ $= 2.51 \times 10^{29}$ kg Since $M_A/M_B = 3$ $M_A = 3M_B = 3 \times (2.51 \times 10^{29}) = 7.53 \times 10^{29}$ kg ER: Answers often did not distinguish clearly between the symbols for quantities related to each star.	 **M1** **A1** **A1**
	(e)		**Essential questions:** 1. How would the further binary star look like when they are in orbit to the observer on Earth? (Note: “cannot be distinguished” implies the two stars cannot be seen as separate/resolved. So even when the two stars are side by side, they appear as “one single ball of light’, but bigger than when one star blocks the other.) **Solution** As the stars’ plane of orbit is parallel to the line of sight, **a periodic change in the size/brightness of the stars can be observed whenever one star is blocked by the other star** (relative to the observer on Earth) (smallest/dimmest when one star blocks the other; largest/brightest when the two stars are side by side). To measure the period of orbit of these stars, the observer could **measure the period of dimming of the stars and multiply by two / time interval between consecutive instances when stars appear smallest and multiply by two.** (refer to Fig. 9.4 to visualise) ER: There were many unrealistic responses, such as putting a mirror on one of the stars or shining a laser beam at them.	**B1** **B1**