PHYSICS

9749

SUGGESTED MARK SCHEME
Maximum Mark: 190

October/November 2023

Paper 1
Multiple Choice

Question	*Key*	*Question*	*Key*	*Question*	*Key*
1	**C**	6	**B**	11	**B**
2	**D**	7	**C**	12	**C**
3	**A**	8	**B**	13	**B**
4	**C**	9	**C**	14	**D**
5	**B**	10	**A**	15	**B**
16	**D**	21	**B**	26	**C**
17	**A**	22	**D**	27	**D**
18	**A**	23	**C**	28	**A**
19	**D**	24	**A**	29	**A**
20	**B**	25	**D**	30	**C**

1 The error varies each time a measurement is take.

2 From graph:

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ &= pr + \frac{1}{2}\left(\frac{q-p}{\cancel{r}}\right)r^{\cancel{2}} \\ &= pr + \frac{1}{2}(q-p)r \\ &= \frac{1}{2}(q+p)r \end{aligned}$$

3 Notice that all options has Ft , which is momentum. So let's focus on momentum.

$$Ft = \Delta p = p = \sqrt{2mE}$$
$$\Rightarrow Ft \propto \sqrt{E}$$

Note: The change in momentum is identical to the initial momentum since the final momentum is zero.

4 Notice the *u* and *v* are speeds, which is the magnitude of velocity.
Apply understanding of relative speed of approach equal to relative speed of separation, taking care of the direction of the bodies.

5 Split the metal into top half (mass m) and bottom half (mass ½ m). Let x be the distance between the c.g. and the centre of top half.

$$\cancel{m}x = \frac{1}{2}\cancel{m}(4-x)$$
$$x = \frac{4}{3} \text{ cm}$$

Distance of c.g. from P, which is 6 cm from P:

$$d = 6 - \frac{4}{3} = 4.7 \text{ cm}$$

6 Read question carefully to deduce that 60% of the loss in KE of wind is converted to electrical output of turbine.

$$\text{Power } = 60\% \frac{\text{drop in } KE}{t}$$
$$VI = 60\% \frac{\frac{1}{2}m\left(u^2 - v^2\right)}{t} = 60\%\left(\frac{1}{2}\right)\left(\frac{m}{t}\right)\left(u^2 - v^2\right)$$
$$= 0.6\left(\frac{1}{2}\right)(9.7)\left(4.0^2 - 1.5^2\right)$$

40 W

7 One year, one orbit. Half year, half orbit.

$$2\pi = 360^\circ$$
$$\pi = 180^\circ$$

8 Based on definition.

9 Interpretation of the diagram is key.
A: spacecraft is falling towards Earth (possible as with any normal object)
B: path is around Earth
(possible with some initial velocity, then spacecraft moves in a circular path dues to centripetal force)
C: Not possible
D: path is away from Earth
(possible if it had an initial velocity, it would just be slowing down as it moves)

10 The average force by N molecules on the wall is dues to the collision of N molecules on the wall. By Newton's 3rd Law, force by molecule on wall equals force by wall on molecules.

$$F_{ave} = N\frac{\Delta mv}{\Delta t} = Nm\frac{\Delta v}{\Delta t} = Nm\frac{2v}{\left(\frac{2p}{v}\right)} = Nm\frac{v^2}{p}$$

Note: $\Delta v = 2v$ due to change in direction. Δt is taken to be the time between consecutive collision with the same wall,

$$\Delta t = \frac{2p}{v}$$

11 Notice that the gas is heated to double its thermodynamic temperature in Kelvin.

$$U = \frac{3}{2}pV = \frac{3}{2}nRT$$
$$\therefore \quad T' = 2T \quad \Rightarrow \quad U' = 2U$$

12 Notice thermal energy is applied, and both P and Q have the same mass.

Since P's temperature increases faster (larger gradient) than Q's, hence P has a smaller heat capacity.

Since P takes a longer time to melt fully (from the point it started to melt), it has a larger specific latent heat of fusion than Q.

13 Note that molar mass is given but question asks for KE of one air molecule.

$$x = x_0 \sin wt \Rightarrow v = wx_0 \sin wt$$
$$\therefore v_0 = wx_0 \Rightarrow v_0 = \left(\frac{2\pi}{3\times10^{-3}}\right)\left(2\times10^{-6}\right)$$
$$= 4.2\times10^{-3} \text{ m s}^{-1}$$
$$KE_{max} = \frac{1}{2}mv_0^2 = \frac{1}{2}\left(\frac{2.9\times10^{-2}}{6.02\times10^{23}}\right)\left(4.2\times10^{-3}\right)^2$$
$$= 4.2\times10^{-31} \text{ J}$$

14 Identify peak to peak timing, and take fraction of period:

$$\frac{\Delta t}{T} = \frac{\text{phase difference}}{360^\circ}$$
$$\frac{10\text{ sq}}{30\text{ sq}} = \frac{\text{phase difference}}{360^\circ}$$
$$\text{phase difference} = 120^\circ$$

15 Apply Malus's Law twice:
$I = I_0 \cos^2 45^\circ \cos^2 45^\circ = 0.25 I_0$

16 Using trigonometry,
$$\sin\theta = \frac{\frac{1}{2}x}{D}$$
Apply given quantities in formula:
$$\sin\theta = \frac{\lambda}{b}$$
$$\Rightarrow \frac{\frac{1}{2}x}{D} = \frac{\frac{c}{f}}{b}$$
$$\Rightarrow \ b = \frac{cD}{2xf}$$

17 Apply information to formula:
$$d\sin\theta = n\lambda$$
$$\frac{1\times10^{-3}}{N}\sin 60^\circ = 2\left(500\times10^{-9}\right)\text{ stationary}$$
$$N = 866$$

18 Double slit experiment so
$$x = \frac{\lambda D}{a}$$
$$\Rightarrow x \propto D$$
$$\Rightarrow x - t \text{ graph \& } D - t \text{ graph same shape}$$

$$\frac{D}{t} = \text{constant,}$$
$$\Rightarrow \text{gradient of } D\text{ - }t \text{ is constant}$$
Note: B is not an option because its gradient is zero, meaning distance D is constant.

19 Protons are positive and will experience an electric force in the direction of the E field, which is downwards, towards Y.

Hence horizontal velocity constant; vertical velocity has constant acceleration. Path is NON-circular.

20 Note **isolated charge** at S is used.

Next, a grid is given, indicating that distances can be found:
SP = 3 sq, SR = $2\sqrt{2}$

$$V = \frac{Q}{4\pi\varepsilon_0 r} \Rightarrow V \propto \frac{1}{r} \Rightarrow \frac{V_P}{V_R} = \frac{r_P}{r_R} \Rightarrow \frac{V_P}{636} = \frac{3}{2\sqrt{2}}$$
$$V_P = 600\text{ V}$$

21 Based on definition

22 For e.m.f. of cell E to be balanced (current in ammeter = 0), the potential difference across the resistance wire must be identical to E.

Due to the direction of the cell (positive to the left) in the main potentiometer circuit, the positive end of E (Y) must be connected to the left, and the negative end of E (X) to the right. (options A and C eliminated)

If option B is chosen, then the p.d. across the resistance wire is fixed and may not match the e.m.f. of E.

Hence D is the best option.

23 As intensity of light increase, resistance of LDR decreases. To get the correct graph, add a constant R to a decreasing R.

24 Magnetic field lines indicates the direction of force on North pole.

Based on the field line, N side will be pulled to the right and the S side will be pulled to the left.

However, field lines are closer at S than at N, hence the leftward force on S is greater than the rightward force on N.

25 From diagram, the electron beam is pushed upwards and rightwards.

Work on identifying the direction of forces by the various fields on the electron:

F_E: always opposite to direction of E field
F_B: use Fleming's LHR to determine.

26 Scientific fact to be known.

27 From *V-t* graph, a.c. source must be used. Eliminate A and C.

For option B, diode in that arrangement will result in no current and hence no p.d. across the resistor at all times.

28 Energy lost by electron results in formation of photon.

$$e\Delta V = hf = \frac{hc}{\lambda}$$

$$\left(1.6\times10^{-19}\right)\left(122.4-30.6\right)=\frac{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)}{\lambda}$$

$$\lambda = 1.3\times10^{-8}\text{ m}$$

29 $p=\dfrac{h}{\lambda}\Rightarrow p\lambda = h = \text{constant}$

Graph in option A shows that $p\lambda$ is constant, no matter what λ is

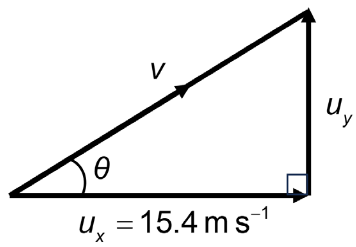
30 Go through the "square ⇒ mean ⇒ root" for the graph. Once the graph is squared, it is a straight line. Hence, the mean-square graph is identical to the square graph. Then we apply root to get V_0.

Paper 2
Structured Questions

General Notes:

Always consider the requirements of the questions fully before attempting answers.
Avoid unnecessary repeating of wording of the question; this takes time and uses up answer space.
For 'show that' questions, need to show the substitution of all numerical values in the formula used.
For formulae derivation, need to show all the algebraic steps clearly.

Question	Suggested Solution	Marks
1(a)	Pressure exerted by water increases with depth hence pressure on bottom surface area of cylinder greater than pressure on top surface area of cylinder. Upwards force on bottom surface larger than downwards force on top surface hence net upwards force is upthrust.	B1 B1
1(b)(i)	Upthrust = Weight of fluid displaced Upthrust $= V\rho g$ $= (27.8\times10^{-6})(1.0\times10^{3})(9.81)$ $= 0.27$ N (shown) Note: Need to give explanation to working	B1 B1
1(b)(ii)	Taking moments about the pivot in Fig. 1.1, Using Principle of Moments, $\sum$ Clockwise moments $=\sum$ Anticlockwise moments $(8.3\times10^{-2})W = (18.0\times10^{-2})F$ - - - (1) Taking moments about the pivot in Fig. 1.2, Using Principle of Moments, $\sum$ Clockwise moments $=\sum$ Anticlockwise moments $(7.8\times10^{-2})W + (0.27)(19.0\times10^{-2}) = (19.0\times10^{-2})F$ - - - (2) Solving (1) & (2), $F = 2.46$ N and $W = 5.34$ N Note: Make sure that moments due to both F and U are considered	C1 C1 A1

Question	Suggested Solution	Marks
2(a)	KE is a minimum at the highest point **and** object is travelling at a speed u_x (horizontal component of v) $KE_{min} = \frac{1}{2}mu_x^2$ $65 = \frac{1}{2}(0.55)u_x^2$ $u_x = 15.4 \text{ m s}^{-1}$ From diagram on the right, $\tan\theta = \frac{u_y}{u_x}$ $\tan 42° = \frac{u_y}{15.4}$ $u_y = 13.9 \approx 14 \text{ m s}^{-1}$  Note: Students to clearly differentiate between vertical and horizontal components of velocity, e.g. with the use of subscripts.	B1 B1 B1
2(b)	Vertical component : $v_y = u_y + a_y t$ $-14 = 14 + (-9.81)t$ time of flight $t = 2.85$ s Horizontal component : $v_x = u_x t$ $= (15.4)(2.85)$ $= 43.9$ m Note: For students who first obtain time to highest point of flight, do remember to double this time to obtain the full duration of flight.	C1 C1 A1
2(c)	When moving upwards, weight of object and air resistance acts downwards and hence resultant force and acceleration will be greater than 9.81 m s^{-1}. When moving downwards, weight of object acts downwards and air resistance acts upwards hence resultant force and acceleration will be smaller than 9.81 m s^{-1}. Since the vertical displacement travelled is the same for both cases, the time taken for the object to reach maximum height is shorter compared to the time taken for the object to return to the ground from maximum height. Note: Simply stating that air resistance acts against motion or that air resistance increases with velocity does not answer the question.	M1 A1

Question	Suggested Solution	Marks
3(a)(i)	$F_g = \dfrac{GMm}{r^2}$ $= \dfrac{(6.67\times10^{-11})(6800)(6.0\times10^{24})}{(6400\times10^3+36000\times10^3)^2}$ $= 1514\text{ N}$ $= 1510\text{ N (3 sig. fig.)}$ Note: Need to add radius of Earth for correct orbital radius, as well as to correctly convert unit from km to m.	C1 A1
3(a)(ii)	For a satellite to undergo circular orbit, Gravitational force Earth on Satellite provides for centripetal force. $F_g = F_c$ $\dfrac{GM\cancel{m}}{r^2} = \cancel{m}r\omega^2$ $T^2 = \dfrac{4\pi^2}{GM}r^3$ Since m represents the mass of the satellite, from the above expression, the period of the geostationary satellite depends only on mass of planet M and radius of orbit r only. Since ***T* is independent of *m***, all geostationary satellites do not need to have a mass of 6800 kg.	B1
3(b)(i)	For ion to undergo circular orbit in magnetic field, Magnetic force on ion provides for centripetal force. $F_B = F_c$ $Bqv\sin\theta = \dfrac{mv^2}{r}$ $r = \dfrac{mv}{Bq\sin\theta}$ $= \dfrac{p}{Bq\sin\theta}$ $\quad (p = mv)$ $= \dfrac{3.4\times10^{-23}}{(1.8\times10^{-3})(1.60\times10^{-19})\sin(90°)}$ $= 0.118\text{ m}$	M1 A1
3(b)(ii)	Since $r = \dfrac{mv}{Bq\sin\theta}$, as radius of orbit is dependent not only on charge of ion, and there is a likelihood that **the ions can have different momentum due to different speed that it is travelling at or different masses** (isotopes of chlorine), they **do not need to have the same radius** of circular path.	B1

Question	Suggested Solution	Marks
4(a)(i)	When (incident) sound waves traveling from the **loudspeaker** reflects **at the metal plate**, the reflected sound waves travel in a direction opposite to the sound waves coming from the loudspeaker. The reflected and (further) incident waves **superpose** at the region between the loudspeaker and metal plate. Since the waves have same frequency/wavelength/period **and** speed **and** is travelling in opposite direction, a stationary wave is formed between the loudspeaker and the metal plate. Note: Answer needs to be applied to context, and not just quote the general condition	B1 B1 B1
4(a)(ii)	Time taken for 2 complete cycles = $(0.50\times10^{-3})\times10 = 0.0050$ s Period $T = \dfrac{0.0050}{2} = 0.0025$ s $f = \dfrac{1}{T} = \dfrac{1}{0.0025}$ $= 400$ Hz (shown)	B1 B1
4(a)(iii)	$v = f\lambda$ $\lambda = \dfrac{v}{f}$ $= \dfrac{340}{400} = 0.850$ m Distance between adjacent nodes = $\dfrac{\lambda}{2} = \dfrac{0.850}{2} = 0.425$ m	 C1 A1
4(b)(i)	Path difference = 1.8 – 1.4 = 0.4 m = 2λ. Since sources are in phase and path difference is an integer multiple of λ. Constructive interference takes place at point P. Therefore, the intensity is a maximum.	M1 A1
4(b)(ii)	Using $I = \dfrac{P}{4\pi r^2}$ and ratio method, $\dfrac{I_X}{I_Y} = \dfrac{r_Y^2}{r_X^2}$ $\dfrac{4.5\times10^{-6}}{I_Y} = \dfrac{(1.8)^2}{(1.4)^2}$ $I_Y = 2.7\times10^{-6}$ W m^{-2}	 C1 A1

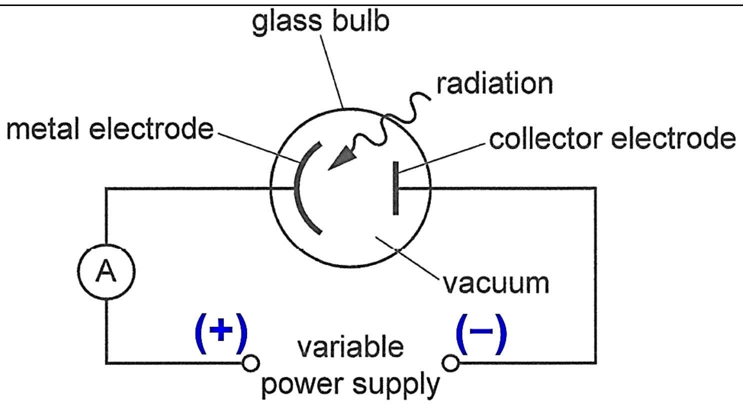
Question	Suggested Solution	Marks
4(b)(iii)	Since $I \propto x_0^2$, using ratio method, $\dfrac{I_X}{I_Y} = \dfrac{x_{0,X}^2}{x_{0,Y}^2}$ $\dfrac{x_{0,X}}{x_{0,Y}} = \sqrt{\dfrac{I_X}{I_Y}}$ $= \sqrt{\dfrac{4.5 \times 10^{-6}}{2.7 \times 10^{-6}}}$ $= 1.29$	C1 A1

Question	Suggested Solution	Marks
5(a)	As p.d. across the thermistor increases from zero, the resistance of the thermistor decreases. Since resistance across a component is the ratio of p.d. across it to the current flowing through it, as p.d. increases, **the ratio of p.d. to current decreases because the reciprocal of the gradient of the straight line from the origin and a point on the *I–V* characteristic graph decreases**. Note: Resistance is NOT the reciprocal of gradient of I-V graph	B1 B1
5(b)(i)	Since the resistors are connected in series, current flowing through resistors are the same. $\dfrac{\text{power dissipated in } 220\,\Omega \text{ resistor}}{\text{power dissipated in } 640\,\Omega \text{ resistor}} = \dfrac{\cancel{I}^2 R_{220\,\Omega}}{\cancel{I}^2 R_{640\,\Omega}}$ $= \dfrac{220}{640}$ $= 0.344$ $= 0.34 \text{ (2 sig. fig.)}$ Note: Students must explain their workings as clearly stated in this question.	M1 A1
5(b)(ii)	The presence of internal resistance increases the effective resistance of circuit and decreases the overall current in the circuit. However, since current is cancelled in the power ratio, (b)(i) only depends on the ratio of the resistance of the resistors. The ratio will remain unchanged.	M1 A1
5(b)(iii)	$R_{\text{eff, series}} = 640 + 220 = 860\,\Omega$ $R_{\text{eff, parallel}} = \left(\dfrac{1}{640} + \dfrac{1}{220}\right)^{-1} = 163.7\,\Omega$ Using $I = \dfrac{V}{R}$ and since power supply have negligible internal resistance, V are the same for both circuits. $\dfrac{I_{\text{series}}}{I_{\text{parallel}}} = \dfrac{\left(\dfrac{V}{R_{\text{eff, series}}}\right)}{\left(\dfrac{V}{R_{\text{eff, parallel}}}\right)} = \dfrac{R_{\text{eff, parallel}}}{R_{\text{eff, series}}} = \dfrac{163.7}{860} = 0.190$	C1 B1 A1
5(b)(iv)	Even though the root-mean-square voltage of the a.c. power supply is not the same as the d.c. power supply, the ratio $\dfrac{I_{\text{series}}}{I_{\text{parallel}}}$ is independent of e.m.f. applied across the resistors. The ratio will remain unchanged.	M1 A1

Question	Suggested Solution	Marks
6(a)	Faraday's Law of electromagnetic induction states that the **induced e.m.f.** in a conductor is proportional to **the rate of change of the magnetic flux linkage.**	B1 B1
6(b)	As wire is oscillating between the region of magnetic field, there is cutting of magnetic flux. By Faraday's Law of electromagnetic induction, an e.m.f. is induced in the wire. Since the wire changes the direction of its motion periodically every half a cycle of oscillation, by Lenz's Law, the direction of the e.m.f. induced will also reverse its direction every half a cycle. Therefore, an alternating e.m.f. is induced across the ends of the wire. Note: Explain in terms of flux cutting instead of change in magnetic flux linkage. It is also necessary to relate change in direction of cutting to the change in direction of emf to fully explain that alternating emf is induced.	B1 B1
6(c)	e.m.f induced $= \left\lvert \frac{\Delta \Phi}{\Delta t} \right\rvert$ $= \left\lvert \frac{\Delta NBA}{\Delta t} \right\rvert$ $= \left\lvert \frac{NBL\Delta x}{\Delta t} \right\rvert$ $= NBLv$ (since $v = \frac{\Delta x}{\Delta t}$) $= (1)(250 \times 10^{-3})(0.15)(0.80)$ $= 0.030$ V Note: the length L is the length of wire within the magnetic field and not the full length of the wire.	 C1 A1
6(d)	As the wire is moving in the region of magnetic field, the same electric potential will be induced at both ends X and Y of the wire. The e.m.f. induced across the ends of X and Y will be 0 V.	M1 A1

Question	Suggested Solution	Marks
7(a)(i)	Photoelectric Effect	B1

<table>
<tr><th>Question</th><th>Suggested Solution</th><th>Marks</th></tr>
<tr><td>7(a)(ii)</td><td>Diffraction/Interference

Note: Electron diffraction is incorrect since question is not asking for the wave nature of particles.</td><td>B1</td></tr>
<tr><td>7(b)(i)</td><td>
Collector needs to be negatively charged to “repel” electrons that is ejected from emitter plate back to the emitter plate when zero current is detected.

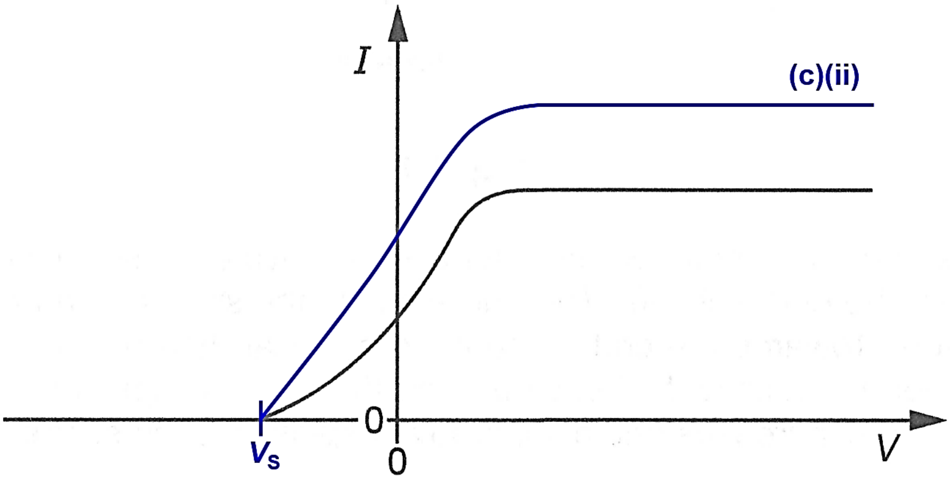
Note: The labelling should be done on the power supply, not the photocell</td><td>B1</td></tr>
<tr><td>7(b)(ii)</td><td>Using Photoelectric equation,
$\begin{pmatrix}\text{energy provided by}\\ \text{a single photon}\end{pmatrix} = \begin{pmatrix}\text{work function energy}\\ \text{of a particular metal}\end{pmatrix} + \begin{pmatrix}\text{maximum kinetic energy}\\ \text{of a photoelectron}\end{pmatrix}$
$(12.4)(1.60\times10^{-19}) = 4.2(1.60\times10^{-19}) + (1.60\times10^{-19})V_S$
$V_S = 8.2\text{ V}$</td><td>C1
A1</td></tr>
<tr><td>7(b)(iii)</td><td>The intensity of the electromagnetic radiation only determines the number of photons arriving at the collector plate per unit time.

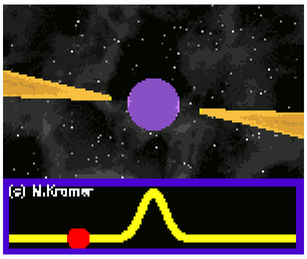
The energy carried by each photon remains the same because the frequency/wavelength of photon is unchanged.

Using the photoelectric effect equation, maximum KE of photoelectron emitted remains the same as work function is unchanged. The stopping potential depends on max KE of photoelectron.</td><td>B1

B1

B1</td></tr>
</table>

Question	Suggested Solution	Marks
7(c)(i) & (ii)		
	Correct label at intersection between curve and horizontal axis. Larger photocurrent throughout. Stopping potential remain unchanged.	B1 B1 B1

Question	Suggested Solution	Marks
8(a)	From t = 0.40 s to 5.20 s, there are a total of 9 signal peaks $\Rightarrow$ 8 intervals $T = \frac{5.20 - 0.40}{8} = 0.60\text{ s}$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{0.60} = 10.5\text{ rad s}^{-1}$ Note: Idea of averaging must be present. Following gif. Can help to explain why intervals between adjacent peaks is period. 	M1 A1
8(b)	When the core collapses under gravitational forces, **the radius of the dying star decreases. Since the angular momentum *L* and mass of the star remains constant, using** $L = \frac{2}{5}mr^2\omega$**, *ω* increases.** Therefore, the pulsar spins faster.	B1
8(c)	The Iron-56 nucleus has the **highest average binding energy per nucleon** (8.8 MeV) compared to all other type of nucleus and hence is the most stable nucleus. Hence, it will not undergo nuclear fusion to form a more stable nucleus.	B1 B1
8(d)(i)	$g_{\text{surface}} = \frac{GM_{\text{pulsar}}}{R_{\text{pulsar}}^2}$ $= \frac{(6.67\times10^{-11})(1.4\times2.0\times10^{30})}{(10\times10^3)^2}$ $= 1.87\times10^{12}\text{ N kg}^{-1}$	C1 A1
8(d)(ii)	$\Delta g = g_{\text{surface}} - g_{\text{surface}+1\text{m}}$ $= \frac{GM_{\text{pulsar}}}{R_{\text{pulsar}}^2} - \frac{GM_{\text{pulsar}}}{(R_{\text{pulsar}}+1)^2}$ $= \frac{(6.67\times10^{-11})(1.4\times2.0\times10^{30})}{(10\times10^3)^2} - \frac{(6.67\times10^{-11})(1.4\times2.0\times10^{30})}{(10\times10^3+1)^2}$ $= 3.73\times10^{8}\text{ N kg}^{-1}$	A1

<table>
<tr><th>Question</th><th>Suggested Solution</th><th>Marks</th></tr>
<tr><td>8(d)(iii)</td><td>The length of the rod will increase as it accelerates towards the surface of the pulsar.

This is because the lower end of the rod will experience an acceleration of 10^8 times larger than the top of the rod. Hence, the force experienced by the lower end of the rod will be greater than the top. Thus, it will be stretched.

Note: Interested students can look up on “spaghettification” to find out more.</td><td>A0

B1</td></tr>
<tr><td>8(e)(i)</td><td>$v = r\omega$
$= (100 \times 10^3)\left(\frac{2\pi}{2.0 \times 10^{-3}}\right)$
$= 3.14 \times 10^8 \text{ m s}^{-1}$
Since the speed of surface is greater than the speed of light ($3.0 \times 10^8 \text{ m s}^{-1}$), this pulsar cannot have a period of 2.0 ms.</td><td>B1
B1</td></tr>
<tr><td>8(e)(ii)</td><td>For pulsar to not disintegrate,
$a_c \leq g_{surface}$
$R\omega^2 \leq \frac{GM}{R^2}$
$R\omega^2 \leq \frac{G\rho V}{R^2}$
$\left(\frac{2\pi}{T}\right)^2 \leq \frac{G\rho\left(\frac{4}{3}\pi \cancel{R}^3\right)}{\cancel{R}^3}$ (Volume of sphere = $\frac{4}{3}\pi R^3$)
$\frac{4\pi^2}{T^2} \leq \frac{G\rho(4\pi)}{3}$
$\frac{3\pi}{GT^2} \leq \rho$ (shown)</td><td>M1
M1
B1
B1</td></tr>
<tr><td>8(e)(iii)</td><td>$\rho = \frac{3\pi}{GT^2}$
$= \frac{3\pi}{(6.67 \times 10^{-11})(0.60)^2}$
$= 3.925 \times 10^{11}$
$= 3.93 \times 10^{11} \text{ kg m}^{-3}$ (3 sig. fig.)</td><td>A1</td></tr>
<tr><td>8(f)</td><td>age $= \frac{\text{period}}{2 \times \text{rate of change of period}}$
$= \frac{33.5 \times 10^{-3}}{2 \times 38 \times 10^{-9}}$
$= 440789$ days
$= 1210$ years

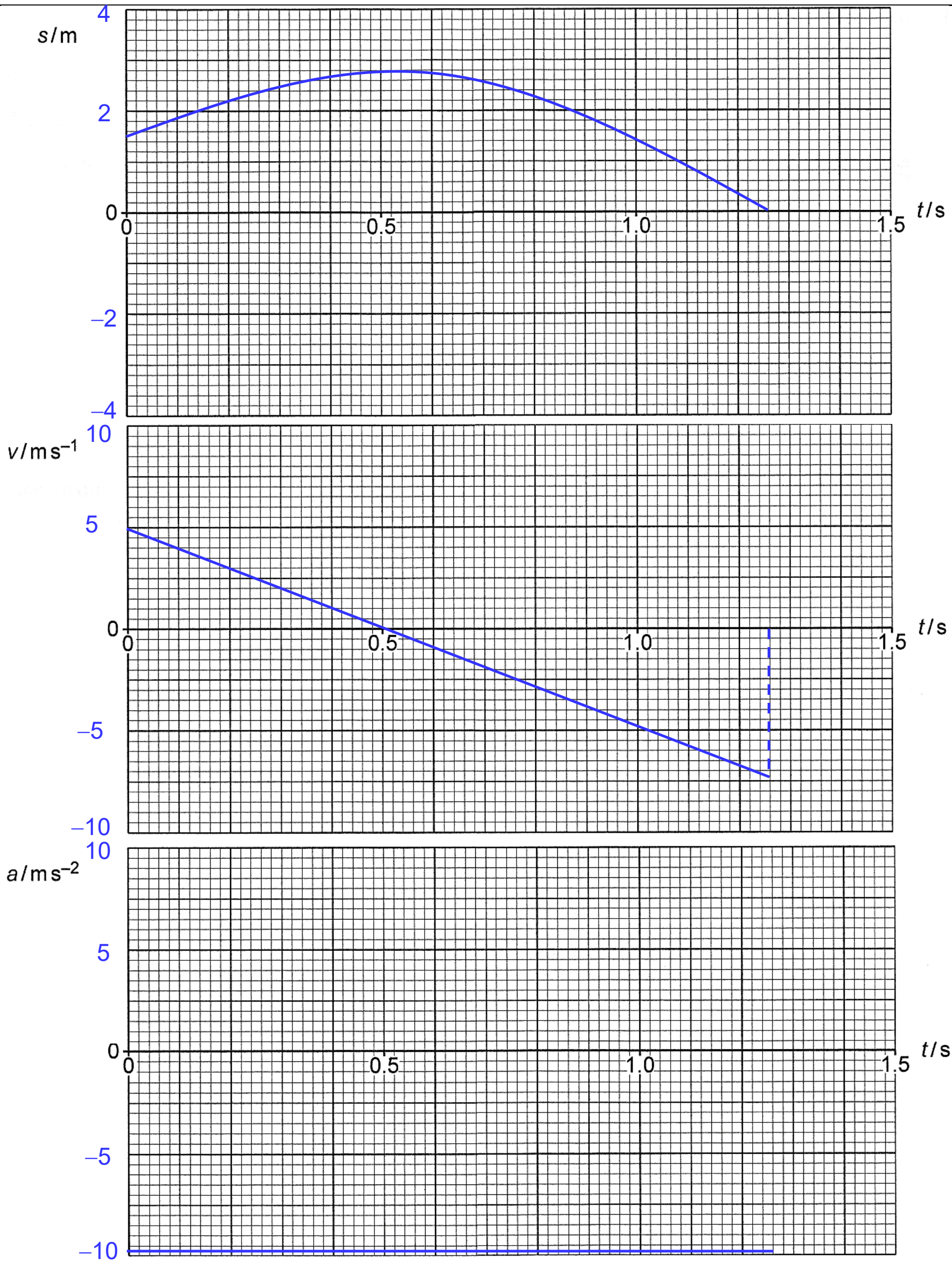
Note: Final answer should be given in years, not days</td><td>A1</td></tr>
</table>

Question	Suggested Solution	Marks
8(g)	$E = hf$ $E = \dfrac{hc}{\lambda}$ $\lambda = \dfrac{hc}{E}$ $= \dfrac{(6.63\times10^{-34})(3.0\times10^{8})}{400\times10^{12}\times(1.60\times10^{-19})}$ $= 3.11\times10^{-21}$ m	 C1 A1
8(h)	A greater effective collecting area of SKA will enable a stronger signal to be detected even for a very weak radio signal sent out from undiscovered pulsar to being picked up because *Power* = *Intensity* × *Area of detector*.	B1

Paper 3
Longer Structured Questions

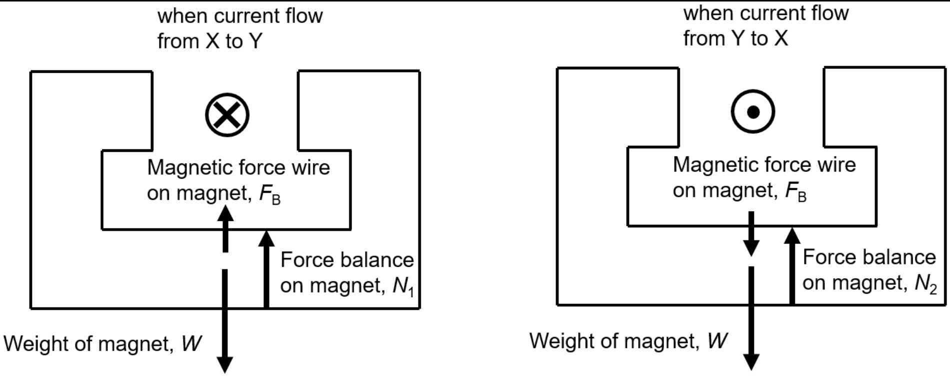
Question		Marks
	General Comments: 1. Need to improve on graphic skills. 2. Explaining phenomenon proves to be more challenging.	
1(a)	$\text{LHS: Units of } x = \text{m}$ $\text{RHS: Units of } \dfrac{L^3 gM}{4wt^3 E} = \dfrac{(\text{m})^3(\text{m s}^{-2})(\text{kg})}{(\text{m})(\text{m})^3(\text{N m}^{-2})}$ $\quad (\text{Pa} = \text{N m}^{-2})$ $= \dfrac{\text{kg m}^4\ \text{s}^{-2}}{\text{m}^4(\text{kg m s}^{-2}\ \text{m}^{-2})}$ $\quad (\text{N} = \text{kg m s}^{-2})$ $= \dfrac{1}{\text{m}^{-1}}$ $= \text{m}$ $= \text{units on LHS } (\therefore \text{ equation is homogeneous})$	B1 B1 B1
1(b)	$x = \dfrac{L^3 gM}{4wt^3 E}$ $E = \dfrac{L^3 gM}{4wt^3 x} = \dfrac{(0.800)^3(9.81)(300\times10^{-3})}{4(2.10\times10^{-2})(4.56\times10^{-3})^3(1.00\times10^{-2})}$ $= 1.89\times10^{10}\ \text{Pa}$ $\dfrac{\Delta E}{E} = 3\dfrac{\Delta L}{L} + \dfrac{\Delta M}{M} + \dfrac{\Delta w}{w} + 3\dfrac{\Delta t}{t} + \dfrac{\Delta x}{x}$ $= 3\left(\dfrac{0.005}{0.800}\right) + \left(\dfrac{2}{300}\right) + \left(\dfrac{0.02}{2.10}\right) + 3\left(\dfrac{0.01}{4.56}\right) + \left(\dfrac{0.01}{1.00}\right)$ $= 0.0515$ $1.89 \times 10^{10}\text{Pa} \pm 5\%$ **Comments:** 3 s.f is expected for value of E.	C1 A1 C1 A1

2(a)(i)	Taking upwards as positive, $v_y^2 = u_y^2 + 2a_y s_y$ $v_y^2 = (5.0)^2 + 2(-9.81)(-1.5)$ $v_y = -7.38\ \text{m s}^{-1}$ Speed of ball is $7.38\ \text{m s}^{-1}$ travelling downwards.	C1 A1

Question		Marks
2(a)(ii)	Taking upwards as positive, $s_y = u_y t + \frac{1}{2} a_y t^2$ $-1.5 = (5.0)t + \frac{1}{2}(-9.81)t^2$ $t = 1.26$ s or -0.242 s (reject) The time of flight of the ball is 1.26 s	C1 A1
2(b)	 Correct signs Suitable scale *s-t* graph peaks at s = 2.77 m when t = 0.509 s. *v-t* graph cuts *t*-axis at t = 0.509 s.	B1 B1 C1 A1 B1

Question		Marks
3(a)	Electric current is the rate of flow of electric charges.	B1
3(b)	Let t be the time taken for the charge carriers to move length l. $I = \frac{Q}{t}$ $= \frac{nqV_{\text{conductor}}}{t}$ $\quad (Q = nV_{\text{conductor}} \times q)$ $= \frac{nqAl}{t}$ $\quad (V_{\text{conductor}} = Al)$ & $(v = \frac{l}{t})$ $= nqAv$ **Comments:** Need to use the same symbols and meaning as specific to this question (e.g. A, l).	B1 B1 B1
3(c)(i)	Using $I = nqAv$, $v = \frac{I}{nqA}$ $= \frac{I}{\left(\frac{N}{\cancel{A}l}\right)q\cancel{A}}$ $= \frac{Il}{Nq}$ $= \frac{(2.00)(3.00)}{(1.45 \times 10^{23})(1.60 \times 10^{-19})}$ $= 2.59 \times 10^{-4}\ \text{m s}^{-1}$ **Comments:** Should use the number density instead of number of conducting electrons for n.	C1 C1 A1
3(c)(ii)	In (c)(i), the drift velocity is the average velocity of all the electrons in one direction along the wire. However, the mean speed of a conduction electron in tungsten wire is much greater than the answer in (c)(i) due to their random thermal motion at room temperature. The root-mean-square speed of the electrons at room temperature of 27°C is of the order 10^5 m s^{-1}. **Comments:** Candidates could not define drift velocity as the average velocity of all the electrons in one direction along the wire.	B1 B1

Question		Marks
4(a)	Magnetic flux density B is the force acting per unit current per unit length on a wire carrying a current that is placed normal to the magnetic field.	B1 B1
4(b)(i)	When current flows in the metal rod, an upwards electromagnetic force acts on the magnet since the reading on the balance decreases. By Newton's Third Law, a downwards electromagnetic force will act on the metal rod. Using Fleming's Left Hand Rule, the direction of the current is determined to be flowing from X to Y. **Comments:** The most common misconception was to say that the force on the wire was the reason for the balance reading to decrease, rather than the force on the magnet.	B1 M1 A1

<table>
<tr><th>Question</th><th></th><th>Marks</th></tr>
<tr><td>4(b)(ii)</td><td>


Since current in rod is the same for both situation, magnetic force on rod is the same for both cases. Using N3L, magnetic force on magnet will also be the same for both cases.

Using FBD(left) drawn for first case :
$F_B + N_1 = W$
$F_B + (m_1)(9.81) = W \quad ---(1)$
Using FBD(left) drawn for second case :
$F_B + W = N_2$
$F_B = (m_2)(9.81) - W \quad ---(2)$

Taking (1) + (2),
$2F_B = (m_2 - m_1)(9.81)$
$2BIL = (202.17\times10^{-3} - 201.62\times10^{-3})(9.81)$
$B = \dfrac{(202.17\times10^{-3} - 201.62\times10^{-3})(9.81)}{2(1.60)(12\times10^{-2})}$
$= 0.0141\,\text{T}$
</td><td>C1

C1

C1

A1</td></tr>
<tr><td>4(b)(iii)</td><td>Since $F_B = BIL \sin\theta$ and current flowing in the new rod remains the same, the magnetic force acting on the rod and hence on the magnet will be the same as in (b)(ii). Hence, there will not be any changes on the readings on the balance.</td><td>A1</td></tr>
<tr><td></td><td></td><td></td></tr>
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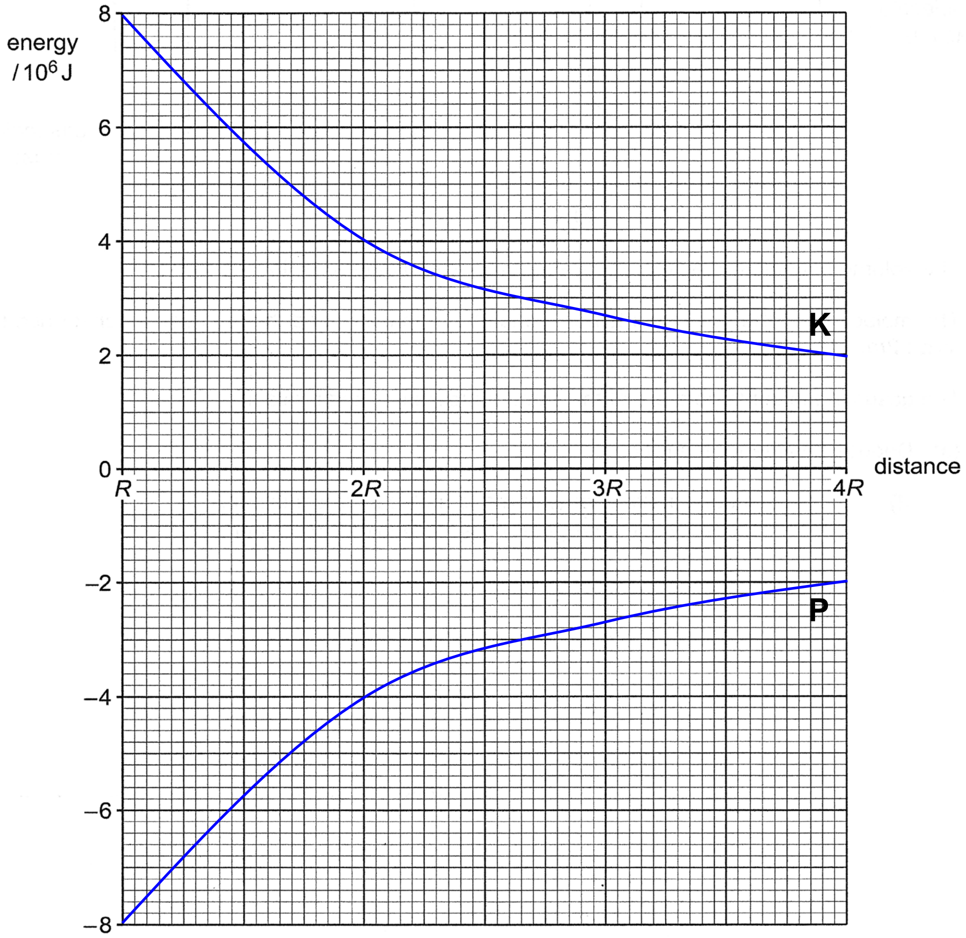
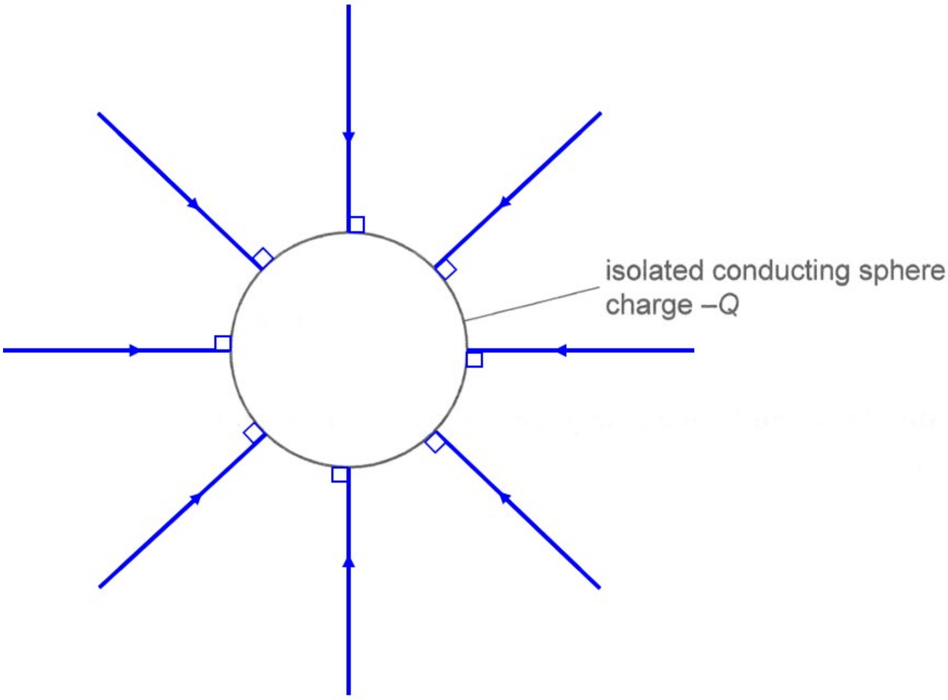
Question		Marks
5(a)	The **gravitational potential** at **a point in the gravitational field** is the work done *per* unit mass in bringing a small test mass from infinity to that point in the field.	B1 B1
5(b)	Using conservation of energy, $\sum E_{\mathrm{i}} = \sum E_{\mathrm{f}}$ $\mathrm{GPE_i} + \mathrm{KE_i} = \mathrm{GPE_f} + \mathrm{KE_f}$ at infinity, GPE = 0 ; KE = 0 as all KE used to overcome GPE $-\dfrac{GMm}{R} + \dfrac{1}{2}mv^2 = 0 + 0$ $v = \sqrt{\dfrac{2GM}{R}}$ **Comments:** Some candidates thought that the energy was only zero at infinity and did not realize that the total energy is zero at all times. Some also mixed up the decrease in kinetic energy and the increase in gravitational potential energy.	 B1 M1 A1

5(c)(i),(ii)	 The projectile in (b) has a total energy of zero because it only possesses just enough energy to escape from the planet. Since it is launched with a KE of 8.0×10^6 J, the GPE it possesses at R will be -8.0×10^6 J. Given that GPE at R : $-\dfrac{GMm}{R}=-8.0\times10^6$ J GPE at $2R$: $-\dfrac{GMm}{2R}=-4.0\times10^6$ J GPE at $3R$: $-\dfrac{GMm}{3R}=-2.67\times10^6$ J GPE at $4R$: $-\dfrac{GMm}{4R}=-2.0\times10^6$ J Increasing curve with decreasing positive gradient. Curve passes through coordinates calculated above. Reflection of curve P about x-axis. Curve passes through correct coordinates. **Comments:** The shapes of the graph were not always correct, and curves were not always well drawn. A significant number of candidates did not label their curves to show which curve represents which type of energy.	 B1 B1 B1 B1

Question		Marks
	Some candidates knew that the potential energy of an object in circular motion is twice that of its kinetic energy and tried to sketch the accompanying graph, which is not what the question was asking for.	

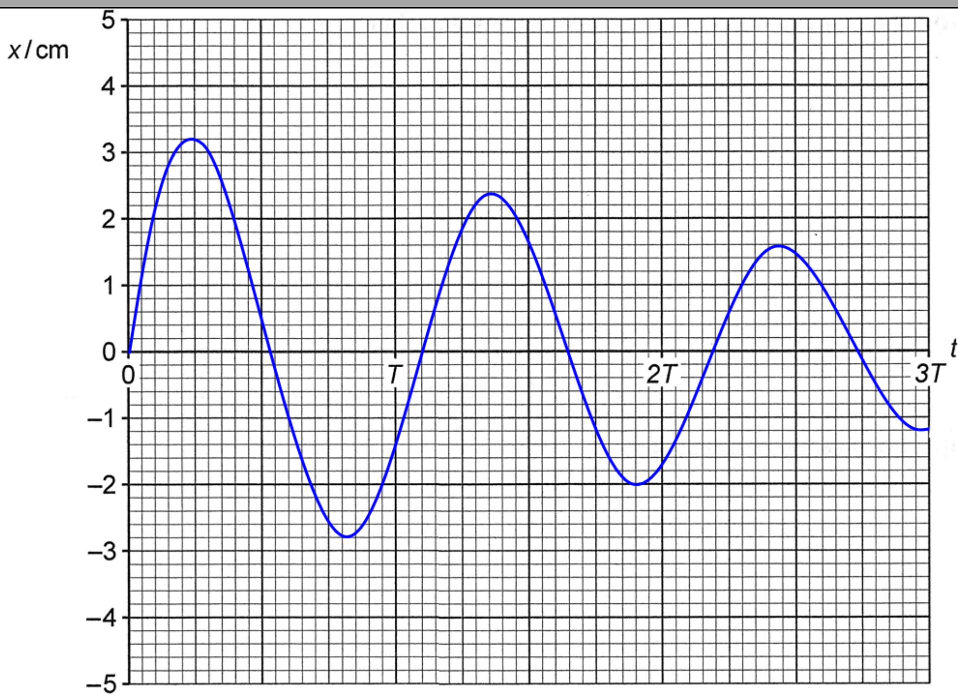
Question		Marks
6(a)(i)	Since temperature in both containers are the same, gas molecules in both containers will possess the same mean KE. Ratio = 1	 A1
6(a)(ii)	Using ideal gas equation : $pV = NkT$ $N = \dfrac{pV}{kT}$ $\therefore \dfrac{N_A}{N_B} = \dfrac{\left(\dfrac{p_A V_A}{kT_A}\right)}{\left(\dfrac{p_B V_B}{kT_B}\right)}$ $= \dfrac{p_A V_A T_B}{p_B V_B T_A}$ $= \dfrac{V_A}{V_B}$ (since $p_A = p_B$ and $T_A = T_B$) $= \dfrac{V}{4V}$ $= 0.25$	
6(a)(iii)	Using kinetic theory equation : $pV = \dfrac{1}{3}Nm\langle c^2 \rangle$ and ratio method, $\dfrac{p_A V_A}{p_B V_B} = \dfrac{\frac{1}{3}N_A m_A \langle c_A^2 \rangle}{\frac{1}{3}N_B m_B \langle c_B^2 \rangle}$ $\dfrac{V}{4V} = \dfrac{(1)(m)}{(4)(2m)}\dfrac{\langle c_A^2 \rangle}{\langle c_B^2 \rangle}$ (since $p_A = p_B$) $\dfrac{\langle c_A^2 \rangle}{\langle c_B^2 \rangle} = 2$ $\dfrac{c_{rms,A}}{c_{rms,B}} = \sqrt{2} = 1.41$ **Comments:** Some candidates found this challenging. Many candidates tried to use the volume of the containers or the number of molecules of each gas as well as the masses.	C1 A1

Question		Marks
6(b)	Using answer in (a)(iii), $\dfrac{c_{\text{rms,A}}}{c_{\text{rms,B}}} = 1.41$ $c_{\text{rms,A}} = (1.41)(940) = 1325 \text{ m s}^{-1}$	C1
	Using kinetic theory equation : $pV = \dfrac{1}{3}Nm\langle c^2 \rangle$ and ideal gas equation : $pV = NkT$ $NkT = \dfrac{1}{3}Nm\langle c^2 \rangle$	C1
	$T = \dfrac{Nm\langle c^2 \rangle}{3Nk}$ $= \dfrac{m\langle c^2 \rangle}{3k}$ $= \dfrac{\left(\dfrac{M_r}{N_A}\right)\langle c^2 \rangle}{3k}$ $= \dfrac{\left(\dfrac{4.0 \times 10^{-3}}{6.02 \times 10^{23}}\right)(1325)^2}{3(1.38 \times 10^{-23})}$	C1
	$= 282 \text{ K}$	A1
	Comments: Many candidates found this question challenging. Many candidates did not realize that the m in the equation for the kinetic energy of a molecule was the mass of one molecule. Many candidates thought that as the mass of gas in container A was 6.4g, then the mass of gas in container B must be 12.8g without realizing that there were four times as many molecules in container B as there were in container A. Many candidates mixed up the molar mass, the number of molecules, the mass of the gas and the mass of one molecule were for each container, and this led to some unrealistic answers.	

Question		Marks
7(a)	Electric field strength *E* at a point in the field is electric force *per* unit positive charge placed at that point.	B1 B1
7(b)(i)	 Direction of field line is radially towards centre of sphere. Field lines are closer near surface of sphere and spread out further away from sphere. Field lines are perpendicular to the surface of the sphere. **Comments:** The lines were not always equally spaced around the sphere and not always perpendicular to the surface.	B1 B1 B1
7(b)(ii)	magnitude of potential gradient = Electric field strength Since sphere is isolated and sphereically symmetrical, $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ $Q = 4\pi\varepsilon_0 r^2 E$ $= 4\pi(8.85\times10^{-12})(0.15+0.40)^2(130)$ $= 4.37\times10^{-9}$ C **Comments:** A significant minority then went on to use the formula for electric potential rather than electric field strength to work out the charge on the sphere.	 B1 C1 A1

Question		Marks
8(a)(i)	force constant k = gradient of $F - x$ graph $= \dfrac{4.00 - 0.00}{0.200 - 0.000}$ $= 20.0\ \text{N m}^{-1}$	A1
8(a)(ii)	At equilibrium, the spring stretches by 0.15 m since the force on it is 3.0 N energy stored in spring = area under $F - x$ graph from x = 0 to 0.15 m $= \dfrac{1}{2}(3.0)(0.15)$ $= 0.225\ \text{J}$	C1 A1
8(a)(iii)	Total GPE transferred by object $= mgh$ $= (3.0)(0.15)$ $= 0.45\ \text{J}$	A1
8(b)	The lost in GPE is not equal to the gain in elastic PE because to lower the mass slowly to its stationary equilibrium position, an upwards external force needs to be supplied during the process. As a result, there will be a negative work done to the mass by the hand. **Comments:** This question proved challenging. A significant number of candidates were not able to explain why the answers to (a)(ii) and (a)(iii) are different.	B1 B1
8(c)	Taking upwards as positive. Spring is stretched by x_0 by weight of mass in (a). There is no resultant forces at equilibrium : $T_{\text{spring}} = W$ $kx_0 = W$ When the object is pulled down by x_0 below equilibrium with a force and released, and at a displacement x above the equilibrium position, $F_{\text{net}} = ma$ (using Newton's 2nd Law) $T'_{\text{spring}} - W = ma$ $k(x_0 - x) - W = ma$ $kx_0 - kx - W = ma$ $W - kx - W = ma$ (since $kx_0 = W$) $-kx = ma$ $\therefore\ a = -\dfrac{k}{m}x$ (shown) **Comments:** A lot of candidates did not realize that the extension given is in addition to that already stretched by the mass when hung from the spring in (a).	B1 B1 B1

Question		Marks
8(d)(i)	Since by s.h.m., $a = -\omega^2 x$ comparing with $a = -\dfrac{k}{m}x$ $\omega = \sqrt{\dfrac{k}{m}} = \sqrt{\dfrac{20.0}{\left(\dfrac{3.0}{9.81}\right)}} = 8.09 \text{ rad s}^{-1}$ Taking upwards as positive, and assuming object is travelling upwards at $t = 0$ displacement - time relationship of object : $x = x_0 \sin(\omega t)$ $= 3.2 \sin(8.09t)$ when $t = 0.50$ s $x = 3.2 \sin\left[(8.09)(0.50)\right]$ $= -2.51 \text{ cm}$ Magnitude of displacement from equilibrium = 2.51 cm **Comments:** Candidates did not always realize that ω was equal to √(k/m). A significant number did not recognise that the calculation had to be in radians.	C1 A1
8(d)(ii)	Taking upwards as positive, and assuming object is travelling upwards at $t = 0$ displacement - time relationship of object : $v = \omega v_0 \cos(\omega t)$ $= 25.9 \cos(8.09t)$ when $t = 0.50$ s $v = 25.9 \cos\left[(8.09)(0.50)\right]$ $= -16.1 \text{ cm s}^{-1}$ The object is moving with a speed of 16.1 m s^{-1} downwards. **Comments:** There were some occasional power of ten errors seen as candidates did not realize that the velocity was being measured in cms^{-1}.	C1 A1

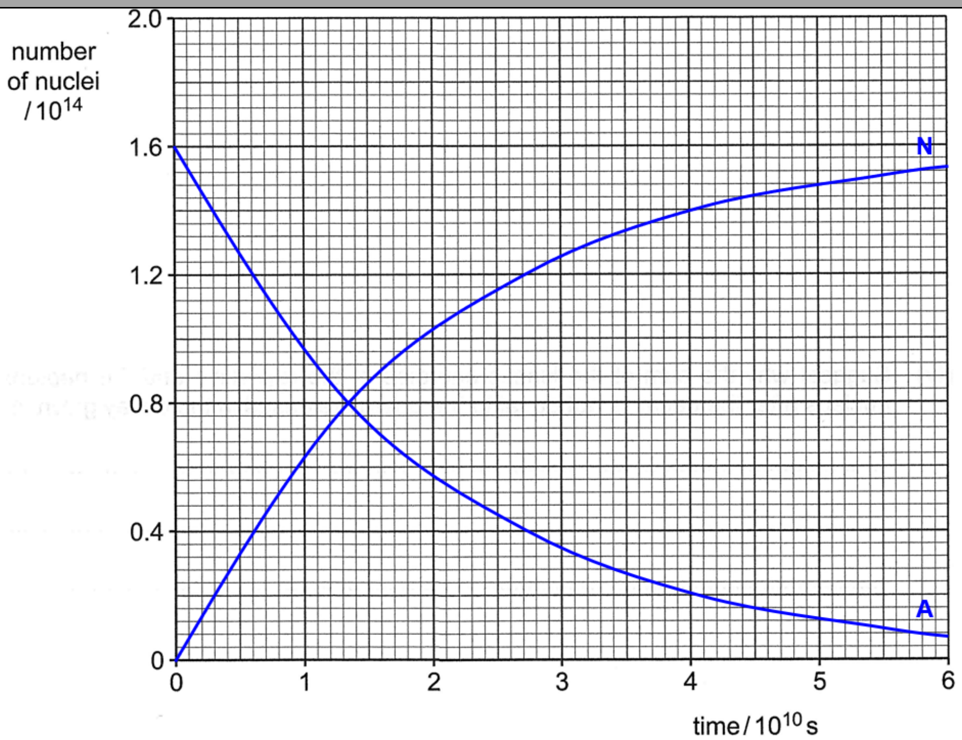
Question		Marks
8(e)	 Decreasing amplitude Period is greater than undamped situation Sinusoidal curve **Comments:** The lightly damped graph was generally of the correct shape although some candidates did not realize that the period remained constant. Most graphs started at the origin, but many candidates did not realize that this meant that the first peak/trough of the graph would be at less than 3.2 cm. Some candidates did not draw the graph with each successive peak or trough being of a smaller amplitude than its predecessor.	 B1 B1 B1
8(f)(i)	The total extension will be 2 times greater (0.30 m). As the springs are connected in series to the object, they both experience a tension of 3.0 N. By Hooke's Law, each spring will have an extension of 0.15 m and hence total extension will be twice that of a single original spring. **Comments:** Candidates found this question challenging. Many candidates did not realize that the extension of the combination would be twice that of the single spring. The idea of a spring constant being a constant for one particular spring only was what candidates found difficult.	B1 B1

Question		Marks
8(f)(ii)	When connected in series, effective spring constant decreases (by half). Hence, ω decreases and period of oscillation will increase. Note: For springs in series, $\dfrac{1}{k_{eff}} = \dfrac{1}{k_1} + \dfrac{1}{k_2}$. **Comments:** Most candidates also found this question challenging. Some candidates did not answer the question in terms of k and correctly relate k to T.	B1 B1

Question		Marks
9(a)(i)	Energy released came from the mass difference between products and reactants $\Delta E = (\Delta m)c^2$ $= (400.19774 - 393.54304 - 6.64466) \times 10^{-27} (3.00 \times 10^{-27})^2$ $= 9.036 \times 10^{-13}$ J $\approx 9.0 \times 10^{-13}$ J (shown) **Comments:** Nearly all candidates answered this question correctly although a few did not give the full working needed in 'show that' questions.	B1 B1
9(a)(ii)	The **Principle of Conservation of Linear Momentum** states that the total linear momentum of an isolated system of interacting bodies before and after collision remains constant if no net external force acts on the system. **Comments:** To say 'momentum is conserved' is a circular definition repeating the stem of the question.	B1 B1

Question		Marks
9(a)(iii)	As alpha decay is a 2 body process, the neptunium - 237 and alpha particles moves in opposite direction when they are formed. By conservation of linear momentum, $\sum p_i = \sum p_f$ $0 = p_{Np} + p_\alpha$ $p_{Np} = -p_\alpha$ Hence, $\lvert p_{Np} \rvert = \lvert p_\alpha \rvert$ Using $KE = \dfrac{p^2}{2m}$, $\sqrt{2m_{Np}(KE_{Np})} = \sqrt{2m_\alpha(KE_\alpha)}$ $KE_{Np} = \dfrac{2m_\alpha(KE_\alpha)}{2m_{Np}}$ $= \dfrac{(6.64466\times10^{-27})(8.784\times10^{-13})}{(393.54304\times10^{-27})}$ $= 1.483\times10^{-14}$ J (shown) **Comments:** The most common mistake was to use the mass numbers of the nuclei and the unified atomic mass unit u instead of the masses given, which are not the same thing. Some candidates tried to answer in terms of energy, which is incorrect.	B1 B1 B1 B1
9(a)(iv)	Some of the energy released during the decay is lost in the form of (gamma) photon. Note: Short calculation will obtain a photon of wavelength = 2.93×10^{-11} m **Comments:** The most common incorrect answer was to say that the extra energy is carried away by a neutrino, which is mixing up alpha and beta decay. Some responses also incorrectly talked about heat energy.	A1

Question		Marks
9(b)(i)	Using $A = \lambda N$, $A_0 = \lambda N_0$ $N_0 = \dfrac{A_0}{\lambda}$ $= \dfrac{8.13 \times 10^3}{5.08 \times 10^{-11}}$ $= 1.60 \times 10^{14}$	 C1 A1
9(b)(ii)	$t_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$ $= \dfrac{\ln 2}{5.08 \times 10^{-11}}$ $= 1.36 \times 10^{10}$ s **Comments:** A few did not give the answer to an appropriate number of significant figures.	A1

Question		Marks
9(b)(iii),(iv)		
	Graph A must cut through the following coordinates : $t = 0$ and $N = 1.6\times10^{14}$ $t = 1.36\times10^{10}$ and $N = 0.8\times10^{14}$ $t = 2{,}72\times10^{10}$ and $N = 0.4\times10^{14}$ $t = 4.08\times10^{10}$ and $N = 0.2\times10^{14}$ $t = 5.44\times10^{10}$ and $N = 0.1\times10^{14}$ $t = 6.00\times10^{10}$ and $N = 0.075\times10^{14}$	B1
	Correct shape	B1
	Graph N must cut through the following coordinates : $t = 0$ and $N = 0$ $t = 1.36\times10^{10}$ and $N = 0.8\times10^{14}$ $t = 2{,}72\times10^{10}$ and $N = 1.2\times10^{14}$ $t = 4.08\times10^{10}$ and $N = 1.4\times10^{14}$ $t = 5.44\times10^{10}$ and $N = 1.5\times10^{14}$ $t = 6.00\times10^{10}$ and $N = 1.525\times10^{14}$	
	Correct shape	B1
	Comments: Candidates generally knew that this was an exponential decay curve, and it was often drawn to a high degree of accuracy. However, some candidates did not produce a curve of sufficient accuracy. Candidates did not always realize that this curve would be the mirror of the curve drawn in (b)(iii). Some also did not label their graphs as instructed.	

Question		Marks
9(c)(i)	Since decay constant of beta emitter is much greater than americium-241, using $A = \lambda N$, with the same initial number of nuclei for both samples, the initial activity of the sample of beta emitter will be much greater compared to the initial activity of americium-241. **Comments:** Most candidates correctly related the activity to the decay constant. Some responses repeated the stem of the question without developing an explanation.	M1 A1
9(c)(ii)	Since the half-life of the beta emitter is much smaller than half-life of americium-241, it will take a shorter time for the activity of the beta emitter to fall to 1 Bq compared to americium-241. **Comments:** Candidates generally understood that the half-life of the beta emitter is shorter than that of the americium-241 but did not always relate that correctly to the time taken.	M1 A1