2024 DHS H2 Physics Prelim Paper 2 Suggested Solutions

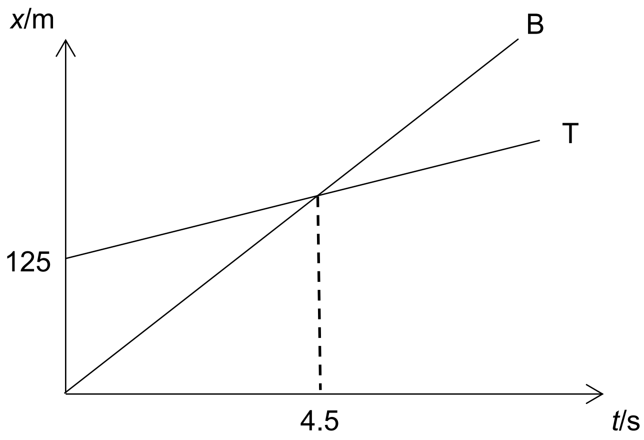
1 **(a)** The bomb is travelling at <u>constant speed</u> in the <u>horizontal direction</u> **B1**
and is <u>accelerating uniformly in the perpendicular (vertical) direction</u> at a rate of 9.81 m s^{-2} (acceleration of free fall) **B1**

MC:	*Generally well answered. Most candidates were able to link their explanations to the definition of projectile motion and hence were able to attain full or minimally partial credit. Most who attained partial credit typically only stated that there is an acceleration in the vertical direction but did not explicitly mention that it is constant.*

(b) $100 = 4.91\ t^2$ **C1**
$t = 4.5$ s **A1**

MC:	*Generally well answered. Some candidate forgot to square in their working.*

(c) **(i)** 2 straight line graphs to show intersect at t = 4.5 s **A1**
and when t = 0, x_{bomb} = 0 and x_{truck} = 125 m **A1**
No indication of values or graph labels: deduct 1 mark



MC:	*Decent attempt. Most candidates were able to obtain the graph above. Common errors included having both graphs start at the origin.*

(ii) v = gradient of truck graph = [(72 x 4.5) – 125] / (4.5) **C1**
= 44 m s^{-1} **A1**

MC:	*Generally well answered. Ecf was should their answers in (b) or (c)(i) be wrong.*

2 **(a)** **(i)** It states that the total momentum of a system of bodies is constant provided no *external resultant* force acts on the system. **B1**

MC:	*This principle applies not only to collision problems e.g. applies during alpha decay as well. In addition, students must explain the meaning of conserve in their answers. It is also not necessary to mention that the system is isolated as no external force would imply such as.*

(ii) By conservation of momentum, **C1**

$(2.4\times3.0) - (1.2\times2.0) = 3.6v$

$v = 1.3 \text{ m s}^{-1}$ **A1**

(iii) Initial total kinetic energy calculated correctly (10.8 + 2.4 = **13.2 J**) and

Final total kinetic energy calculated correctly (**3.2 J**) **M1**

Since total kinetic energy of system is not constant, the collision is inelastic. **B1**

OR

relative speed of approach = 5.0 m s^{-1}, relative speed of separation = 0 m s^{-1} **M1**

Since relative speed of approach is not equal to relative speed of separation, the collision is inelastic. **B1**

MC:	*As it is a 'show' type of question, answers need to be written in full with no short form used, i.e. KE is not accepted but have to spell out as kinetic energy.*

(b) **(i)** By Newton's second law, there is a net downward force by the rotor on the air to increase the momentum of air. **B1**

By Newton's third law, the air exerts a force of equal magnitude but upward direction (i.e. lift force) on the rotor. **B1**

Since the helicopter is hovering, by Newton's first law, the net force on helicopter is zero, that is, lift force = weight of helicopter. **B1**

(ii) volume of air displaced downwards V

= cross-section area of air x distance moved by the air in 5 seconds

$= \pi(5.0^2)(12)(5.0)$

mass of air displaced downwards in 5 seconds

= volume of air x density of air

$= \pi(5.0^2)(12)(5.0)(1.3)$ **C1**

= 6100 kg (2 s.f.) **A0**

MC:	*As it is a 'show' type of question, answers need to be written in full, before any substitution of values. Any symbols used must be defined.*

(iii) By Newton's second law, F = rate of change of momentum

$$= \frac{6000}{5.0}(12) \qquad \textbf{C1}$$

$$= 1.4 \times 10^4 \text{ N} \qquad \textbf{A1}$$

MC:	*Some students mistakenly took the mass of air propelled downwards as the mass of the helicopter.*

3 **(a)** The density of fluid ρ, the cross-section area A of tube, the total mass M of tube and sand and g is constant, **B1**
hence acceleration a is proportional to displacement x from the equilibrium position. **B1**
The negative sign indicates that acceleration a is in opposite direction to displacement x from the equilibrium position. **B1**
These indicate that the motion of the tube is simple harmonic where $a = -\omega^2 x$.
A0

(b) $\omega^2 = \frac{\rho A g}{M}$

$$= \frac{(1.2 \text{ x } 10^3)(5.3 \text{ x } 10^{-4})9.81}{130 \text{ x } 10^{-3}}$$

$$= 48 \text{ rad}^2 \text{ s}^{-2} \qquad \textbf{C1}$$

$$f = \frac{\omega}{2\pi} = 1.1 \text{ Hz} \qquad \textbf{A1}$$

MC:	*There were some careless mistakes in converting cm² to SI units. In addition, some students mistakenly thought* ω = 48 rad s^{-1}.

4 **(a)** The re-drawn Fig. 4.1 is as follows i.e. R_1, R_3 and (R_2, R_4 in series) are in parallel across X and Y.

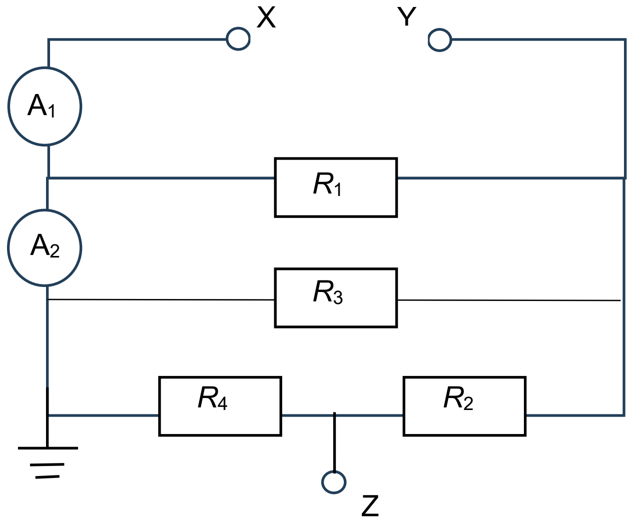


Fig. 4

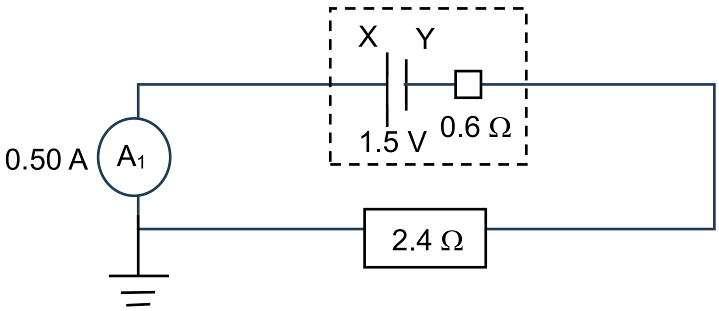
The effective resistance is $\left(\frac{1}{R}+\frac{1}{R}+\frac{1}{2R}\right)^{-1} = 0.4R$ **M1**

$0.4R = 2.4$

$R = 6.0\ \Omega$ **A0**

MC:	*There are different ways to view the re-drawn Fig. 4 to solve the (b)(i) to (iii). Below is the working that should be clear enough for you to understand.*

(b) **(i)**



Total resistance = $2.4+0.6 = 3.0\ \Omega$ **M1**

Current in A_1 = $\frac{E}{R} = \frac{1.5}{3.0}$ = 0.50 A **A1**

(ii) Terminal potential difference between X and Y

$= \frac{2.4}{3.0} \times 1.5 = 1.2$ V **M1**

Current through resistor $R_1 = \frac{V}{R} = \frac{1.2}{6.0} = 0.20$ A **B1**

Thus, current in $A_2 = 0.50 - 0.20 = 0.30$ A **A1**

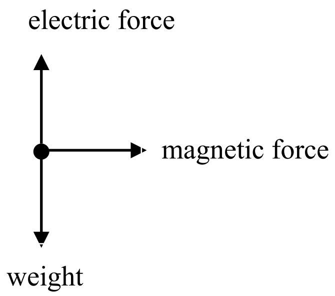
(iii) Potential difference across $R_4 = \frac{6.0}{6.0 + 6.0}$ = x 1.2 = 0.60 V **M1**

Potential at Z = 0 – 0.60 = –0.60 V **A1**

(iv) As reading is zero, the potential difference across S is 0.6 V. **C1**

The potential difference across S = $\frac{S}{S+0.60} \times 1.5 = 0.60$ V

Hence S = 0.4 Ω **A1**

5(a)(i)	The **magnetic force** acting on the charged particle provides the **centripetal force** for the charged particle to move in uniform circular motion.	**B1**
	 $Bqv\sin\theta = ma_c = mv\left(\frac{2\pi}{T}\right)$ $T = \frac{2\pi m}{Bq}$ The circular motion is horizontal, so the net vertical force is zero. $mg = qE$	**C1**
	Combining both equations, $T = \frac{2\pi m}{Bq}$	**C1**
	$= \frac{2\pi E}{Bg}$ (Shown)	**A0**

CKW MC	• Some students stated that both the magnetic force **and** electric force (or sometimes even just the electric force) provide the centripetal force, which was a misconception! Though not credited, an initial free body diagram to identify the correct forces acting on the charged particle in the problem will be a useful starting approach. • The equation based on vertical equilibrium i.e. (1) could not be derived or was not shown separately by quite a number of students. • Some students wrote $F = ma = mg$ for the vertical direction, which is conceptually incorrect application of Newton's 2nd law, since there is no acceleration in the vertical direction i.e. $a = 0$. Thus, $mg = qE$ means that the magnitude of the weight of the particle, mg is equal to the magnitude of the electric force, qE on the particle	
5(a)(ii)	From (i), $T = \frac{2\pi E}{Bg} = \frac{2\pi(150)}{(0.50)(9.81)}$ = **192 s**	**A1**
CKW MC	This part is well done, except for a few students who make careless mistakes.	
5(b)	When the electric field is removed, the only **vertical force** acting on the charged particle is its **weight**. Hence, the particle ***falls with uniform acceleration*** *g*. The magnetic force still provides the centripetal force for the charged particle to movie in uniform horizontal circular motion, resulting in the charged particle moving in a **helical** path in which the ***distance between adjacent loops increases*** as the particle falls. Using Fleming's Left-hand Rule, the charged particle will continue to move in a **clockwise circle when viewed from the top** of its helical path.	**B1** **B1** **B1**
CKW MC	• Many students use inappropriate terms such as "spiral" or did not state the consequences of a net force due to weight based on Newton's 2nd Law. • Most students did not state the direction of the charged particle in its helical motion and from the correct perspective.	

6 **(a)** Photons are produced whenever a **charged particle** such as electrons **decelerates**. **B1**

The electrons produced from the cathode will strike the metal target and decelerates. Since the electrons has a **distribution of decelerations**, the X-ray photons produced also has a distribution of wavelengths. Hence a continuous spectrum is produced. **B1**

MC:	*Generally very poorly done. Many candidates quoted either the explanation for characteristic emissions or phenomena completely unrelated to X-ray production such as line spectra, discrete energy levels, radioactive decay or photoelectric effect.* *Amongst those that managed to produce some semblance of the above answer, most did not state explicitly the mechanism in which photons can be produced using charged particles. However, most were able to identify that the electrons will decelerate to different extents (or lose different amounts of KE) which gives rise to the continuous background.*

(b) **(i)**

$$\frac{hc}{\lambda_{\text{min}}} = eV$$

$$\lambda_{\text{min}} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.6\times10^{-19}\times10000}$$ **C1**

$$= 1.2431\times10^{-10}$$

$$= 1.24\times10^{-10}\text{m}$$ **A1**

MC:	*Generally very poorly done. Most candidates could not link the minimum wavelength to the accelerating potential but instead attempted to use energy differences in the energy level diagram to calculate their answers.*

(ii) For K_α line,

$$|E_2 - E_1| = \frac{hc}{\lambda_\alpha}$$

$$\lambda_\alpha = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{(-952+8980)\times1.6\times10^{-19}}$$ **C1**

$$= 1.5485\times10^{-10}\text{ m}$$

$$= 1.55\times10^{-10}\text{ m}$$ **A1**

For K_β line,

$$|E_3 - E_1| = \frac{hc}{\lambda_\beta}$$

$$\lambda_\beta = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{(-75.0+8980)\times1.6\times10^{-19}}$$

$$= 1.39599\times10^{-10}\text{ m}$$

$$= 1.40\times10^{-10}\text{ m}$$ **A1**

Note: C1 awarded for any correct substitution for either K_α or K_β.

MC:	*Generally very poorly done. Most students were not aware of the energy level transitions that produces the K_α and K_β lines. Despite it being labelled in the diagram to further aid students, many ended up with a $\lambda_\alpha < \lambda_\beta$.*

(c) By Heisenberg's Uncertainty principle,

$$\Delta p\Delta x \geq h$$

$$m\Delta v\Delta x \geq h$$

$$\Delta v \geq \frac{h}{m\Delta x} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times10^{-15}} = 7.3\times10^{11}\text{ m s}^{-1}$$ **C1**

Since the required velocity of electrons Δv is greater than the speed of light of 3.0×10^{8} m s^{-1}, the electrons does not exist inside the nucleus. **A1**

<table>
<tr><td>MC:</td><td>Generally very poorly done. Quite a significant number did not attempt the question. Most candidates who attempted the question were also unable to make connections to the speed of light.

<u>Common errors:</u>
Using the de Broglie wavelength equation to do the calculations. (either to compute p or λ to be used in the Heisenberg's Uncertainty relation)
Stating that the electron has a momentum of $\sqrt{2mE} = \sqrt{2mqV}$ where V is the accelerating potential in the earlier part. (This is incorrect as the V is an externally applied potential difference. The electron will not exist in the nucleus even in the absence of this potential difference.)</td></tr>
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7 **(a)** Neutron **A1**

$x = 4$ **A1**

(b) **(i)** The binding energy of a nucleus is the <u>minimum energy</u> required to <u>completely separate the nucleus into its constituent nucleons</u> (protons and neutrons) <u>to infinity</u>. **B1**

MC:	*Generally very poorly done. Most students were lacking in keywords in their definitions*

(ii) $E_{released} = BE_{products} - BE_{reactants}$

$= 139\ (8.39) + (5\ (8.74) - 235\ (7.60)$ **C1**

$= 210.51$ MeV

$= 3.36816 \times 10^{-11}$ J

$= 3.37 \times 10^{-11}$ J **A1**

MC:	*Generally not very well done. Most students missed out that the information given is the binding energy* ***per nucleon****, and hence did not multiply the mass numbers in their workings.* *A small handful had erroneous conversion of MeV into J.*

(iii) (loss in mass) $c^2 = E_{released}$

(loss in mass) $(3.00 \times 10^8)^2 = 3.36816 \times 10^{-11}$ **C1**

(loss in mass) $= 3.74 \times 10^{-28}$ kg **A1**

MC:	*Generally well done. Ecf was given should their answer in (ii) be incorrect.*

(iv) When more energy is being released in a nuclear reaction, more stable daughter nuclei are formed as a result. **B1**

Since reaction 1 releases more energy than reaction 2, **B1**

reaction 1 is more likely to occur. **B1**

MC:	*Generally well done. Ecf was given should their answer in (ii) be incorrect. Students' conclusion and explanations should be adjusted according to their answer in (b)(ii). (i.e. if the energy released obtained in (ii) is lower than reaction 2, students must conclude that reaction 2 is more likely to occur to attain credit)* *A small handful of students mixed up the concepts of spontaneity of reactions with the likelihood of reactions. Students are advised not to haphazardly introduce scientific terms outside of what the question has stated or is required to answer the question to avoid being marked down unnecessarily.*

8(a)	Gravitational field is a **region of space** in which a **mass** will experience a **non-contact gravitational** force.	**A1**
CKW MC	• This definition was assessed in 2017 & 2018 H2 P3. • Refer to DHS "Gravitational Field" notes for reference. • Many candidates confused *gravitational field* with *gravitational field strength*. • An *area* is not the same as a *volume* or *region*. • For definitions, avoid using the root words again. Thus, candidates should explain the words *gravitational* and *field* separately.	
8(b)(i)	$\rho = \frac{M}{V} = \frac{M}{\left(\frac{4}{3}\pi r^3\right)} = \frac{0.73}{\left(\frac{4}{3}\pi(25 \times 10^{-3})^3\right)}$ $= 11000$ kg m^{-3}	**C1** **A1**
CKW MC	There was quite a number of students who did not use the correct formula for the volume of a sphere or know the importance of the word "diameter".	
8(b)(ii)	Unit of $\tau =$ Unit of $\frac{2\pi^2 mL^2\theta}{T^2}$ N m = kg m s^{-2} m = $\frac{\text{kg m}^2}{\text{s}^2}$ Unit of θ Unit of $\theta = 1$ $\tau = \frac{2\pi^2 mL^2\theta}{T^2}$ $1.2 \times 10^{-5} = \frac{2\pi^2(0.730)(1.80)^2\theta}{(14.0 \times 60)^2}$ $\theta = 0.18136$ rad $= 0.18136\left(\frac{360}{2\pi}\right)^{\circ} = 10(.4)^{\circ}$	 **C1** **A1** **A1**
CKW MC	• Most students did not realise the unit of θ in the given equation is in radians. • Some students used 2*m* instead of *m*.	

8(b)(iii)	Radius of large sphere, $R = D/2 = 15.0 \text{ cm}$ Radius of small sphere, $r' = d/2 = 25 \text{ mm} = 2.5 \text{ cm}$ Thus, $r = r' + R + \text{air gap width}$ $= 15.0 + 2.5 + 0.1$ $= 17.6 \text{ cm}$	**B1** **C1** **A0**
CKW MC	• Quite a number of students attempted to use Newton's law of gravitation for this part using the given value of torque! • It is also not possible to use the given torque in **(b)(ii)** for this part since it is a different experiment, and the torque is different for *M* = 158 kg as can be shown that $LF_g = L\left(\frac{GMm}{r^2}\right) = 1.2 \text{ x } 10^{-5}$ $r = \sqrt{\frac{LGMm}{1.2 \text{ x } 10^{-5}}} = \sqrt{\frac{(1.8)(6.67 \text{ x } 10^{-11})(158)(0.73)}{1.2 \text{ x } 10^{-5}}} \neq 0.176 \text{ m}$	
8(b)(iv)	Using $s = (L/2)\theta_1$, $4.1 \text{ x } 10^{-3} = (1.8/2)\theta_1$ $\theta_1 = 4.5\dot{5} \text{ x } 10^{-3} \text{ rad}$ The uncertainty equation is given by $\frac{\Delta\theta_1}{\theta_1} = \frac{\Delta s}{s} + \frac{\Delta L}{L}$ $\frac{\Delta\theta_1}{4.5\dot{5} \text{ x } 10^{-3}} = \frac{0.1}{4.1} + \frac{0.01}{1.80}$ $\Delta\theta_1 = 0.1 \text{ x } 10^{-3} \text{ rad}$ $\theta_1 = (4.6 \pm 0.1) \text{ x } 10^{-3} \text{ rad}$	**A1** **C1** **A1**
CKW MC	The max-min method will lead to the same answer.	

8(b)(v)	At θ_1, the torque caused by the gravitational attraction (between *M* and *m*) was equal to the opposing torque caused by the torsion in the wire. Thus, from **(b)(ii)**, $LF_g = \frac{2\pi^2 mL^2\theta}{T^2}$ $L\frac{GMm}{r^2} = \left(\frac{2\pi^2 mL^2}{T^2}\right)\theta_1$ $G = \frac{2\pi^2 Lr^2\theta_1}{MT^2}$ (Shown)	**B1** **C1** **A0**
	OR The maximum **restoring force** is equal to the **gravitational force between the large and small spheres** at a separation of *r*.**.** Thus, $\lvert F_g \rvert = ma = m\omega^2 x_o$ $\frac{GMm}{r^2} = m\left(\frac{2\pi}{T}\right)^2 x_o$ $G = \left(\frac{4\pi^2}{T^2}\right)\frac{r^2}{M}x_o$ The amplitude x_o of the simple harmonic motion is approximately equal to $\frac{L}{2}\theta_1$. Thus, $G = \left(\frac{4\pi^2}{T^2}\right)\frac{r^2}{M}\left(\frac{L}{2}\theta_1\right)$ $G = \frac{2\pi^2 Lr^2\theta_1}{MT^2}$ (Shown)	**B1** **C1** **A0**

CKW MC	Many candidates seem to have the misconception that gravitational force *is* the torque **and/or** the squared term for *L* gets omitted or incorrectly simplified in one step e.g. $$\frac{GMm}{r^2} = \left(\frac{2\pi^2 mL^2}{T^2}\right)\theta_1$$ $$G = \frac{2\pi^2 Lr^2\theta_1}{MT^2}$$	
8(c)(i)	When the rod rotates by an angle of θ_2, the laser beam deflects by an angle of $2\theta_2$ since the angle of incidence of the laser beam is equal to its angle of reflection. Thus, Using $s_2 = D_2(2\theta_2)$, $15.6/100 = (12.00)(2\theta_2)$ $\theta_2 = 0.00650 \text{ rad}$ $= 0.00650 \left(\frac{360}{2\pi}\right)^{\circ}$ $= 0.372^{\circ}$	C1 A0
	OR Using small angle approximation, $2\theta_2 \approx \frac{s_2}{D_2} \quad \rightarrow \quad \tan(2\theta_2) = \sin(2\theta_2) = \frac{s_2}{D_2}$ $\tan(2\theta_2) = \sin(2\theta_2) = \frac{15.6/100}{12.00}$ $\theta_2 = 0.372^{\circ}$	C1 A0
CKW MC	Candidates should show all relevant substitutions and conversion.	

8(c)(ii)	¾ of a period is equal to 10 mins 22 s. Thus, $\frac{3}{4}T = ((10)(60)+22)$ s $T = \frac{2488}{3}$ s From **(b)(v)**, $G = \frac{2\pi^2 L r^2 \theta_2}{MT^2}$ $= \frac{2\pi^2(1.80)(17.6/100)^2(0.00650)}{(158)(2488/3)^2}$ $= 6.58 \text{ x } 10^{-11}$ m^3 kg^{-1} s^{-2} Unit of G = Unit of $\frac{2\pi^2 L r^2 \theta_2}{MT^2}$ $= \frac{\text{m m}^2}{\text{kg s}^2}$ $=$ m^3 kg^{-1} s^{-2}	**M1** **C1** **A1** **A1**
CKW MC	• Most students did not realise the unit of θ_2 is in radians, and conversion needs to be performed for the θ_2 in degrees in **(c)(i)** if used. • Radian is not an SI base unit.	
8(c)(iii)	T will be determined by **taking the average of a large number** of oscillations (about 60 instead of about 1 oscillation as in (b)(ii)) with the **same actual uncertainty**, thus the **percentage (or fractional)** uncertainty of T will be **reduced** significantly.	**A1**
CKW MC	Quite a number of students did not use appropriate and specific terms in their answers such percentage and/or actual uncertainty.	
8(c)(iv)	The rod was assumed to be light.	**A1**
CKW MC	• Most candidates did not provide the **main** reason for the difference in T leading to a difference in G. • The system rotates so slowly in 1 oscillation (T = 14 min) that the damping of air resistance is negligible.	