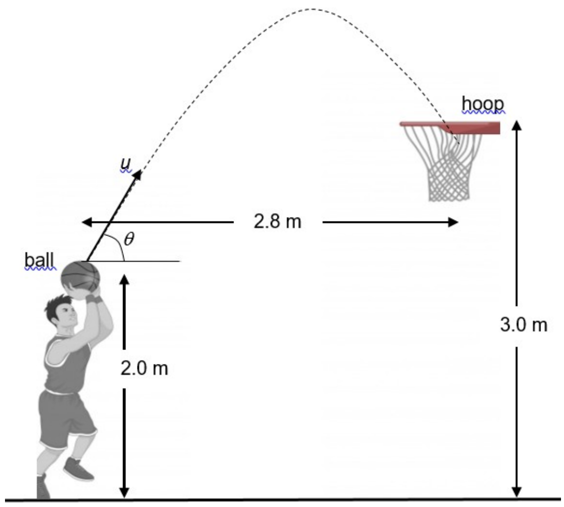
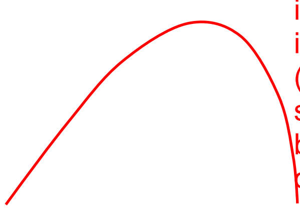
2021 JC2 H2 Preliminary Examination Paper 3 Suggested Solutions

1			$m = \frac{T^2 k}{4\pi^2}$ $= \frac{3.2^2(250)}{4\pi^2}$ $= 64.846$ kg $\frac{\Delta m}{m} = 2\frac{\Delta T}{T} + \frac{\Delta k}{k}$ $\Delta m = (2\frac{\Delta T}{T} + \frac{\Delta k}{k})\, m$ $= (2\frac{0.01}{3.20} + \frac{5}{250})\ 64.846$ $= 1.7$ kg Thus, mass of the astronaut = (65 ± 2) kg	1 1 1
2	**(a)**	**(i)**	$s_y = u_y t + \frac{1}{2} a_y t^2$ $\Rightarrow 1.0 = u_y(1.1) + \frac{1}{2}(-9.81)(1.1)^2$ $\Rightarrow u_y = 6.30$ m s^{-1}	1 1
		(ii)	$s_x = u_x t$ $\Rightarrow 2.8 = u_x(1.1)$ $\Rightarrow u_x = 2.545$ Thus, $\theta = \tan^{-1}(\frac{u_y}{u_x})$ $= \tan^{-1}(\frac{6.305}{2.545}) = 68.0^\circ$	1 1 1

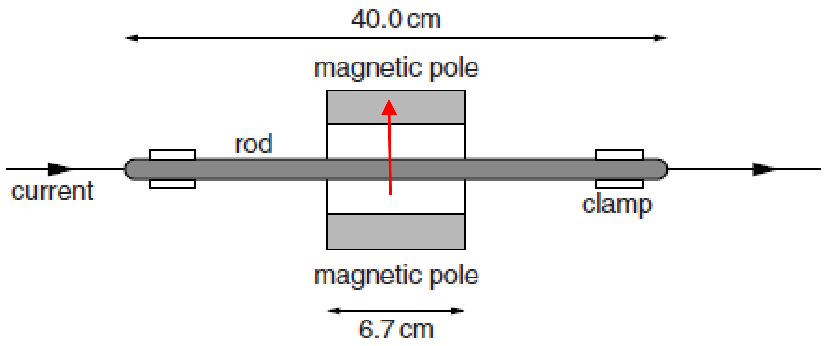
	(b)	 	Maximum height is lower and range is smaller [1] (highest point should therefore be to the left of the original path) Path is asymmetrical [1]

3	(a)	The spring does not obey Hooke's Law. The straight line in the graph does not pass through the origin OR The tension force in the spring is not proportional to the extension. *** Answer must derive evidence from the graph.**	1 1
	(b)	Remove the masses and the spring should return to its original length if the spring is not permanently deformed.	1
	(c)	Work done is obtained from the area under the graph multiplied by *g*. *** Student must attempt to explain the approach taken.** Work done = $\frac{1}{2}[(70 + 145) \times 10^{-3}] \times 120 \times 10^{-3} \times 9.81$ = 0.127 J (0.13 J)	1 1 1
4	(a)	By the principle of conservation of energy, $KE_{Xi} + KE_{Yi} + GPE_{Xi} + GPE_{Yi} = KE_{Xf} + KE_{Yf} + GPE_{Xf} + GPE_{Yf}$ + WD against friction $0 + 0 + 0 + 0 = KE_{Xf} + KE_{Yf} + (4.0)(9.81)(3.0 \sin 30^0) + (5.0)(9.81)(-3.0) + (10.0)(3.0)$ $KE_{Xf} + KE_{Yf} = 58$ J (or 58.3 J) *** Correct calculation of change in GPE of X and change in GPE of Y [M1]** *** Correct substitution in COE equation [M1]**	2 1
	(b)	Since X and Y are connected by an inextensible cord, both bodies attain the same final speed. $\frac{1}{2}(4.0 + 5.0)v^2 = 58.3$ $v_X = v_Y = 3.6$ ms^{-1}	1

5	**(a)**	**(i)**	The centripetal force is provided by the gravitational force acting on stars A and B. By Newton's Third Law, the gravitational force acting on stars A and B are of equal magnitude and opposite direction. Hence, the centripetal force acting on both stars has the same magnitude.	**1** **1**
		(ii)	$\omega = \frac{2\pi}{T}$ $= \frac{2\pi}{4.0 \times 365 \times 24 \times 60 \times 60}$ $\omega = 5.0 \times 10^{-8}$ or 4.98×10^{-8} rads^{-1}	 **1** **1**
	(b)	**(i)**	Since the centripetal force acting on star A and B are of equal magnitude. $M_A \omega^2 d = M_B \omega^2 (2.8 \times 10^8 - d)$ $\frac{M_A}{M_B} = \frac{(2.8 \times 10^8) - d}{d} = 3.0$ $4d = 2.8 \times 10^8$ $d = 7.0 \times 10^7$ km	**1** **1** **1**
		(ii)	Gravitational force provides for the centripetal force acting on star A. Hence, $\frac{GM_A M_B}{(2.8 \times 10^8 \times 10^3)^2} = M_A \omega^2 d$ $M_B = \frac{(4.98 \times 10^{-8})^2 (7.0 \times 10^7 \times 10^3)(2.8 \times 10^{11})^2}{6.67 \times 10^{-11}}$ $M_B = 2.0 \times 10^{29}$ kg	**1** **1** **1**
6	**(a)**	**(i)**	Upthrust and Weight	**1**
		(ii)	At equilibrium, the magnitude of upthrust and weight are equal. When the tube is pushed downwards, the magnitude of upthrust increases. Since the weight of the tube remains constant, the resultant force is upwards	**1** **1**
	(b)		Since $\frac{A\rho g}{M}$ is a constant, acceleration of the tube is proportional to its displacement The negative sign indicates that acceleration and displacement are in the opposite direction	**1** **1**
	(c)	**(i)**	Period of the oscillation = 2.2 s Angular frequency = $2\pi/T$ $= 2\pi/2.2$	 **1**

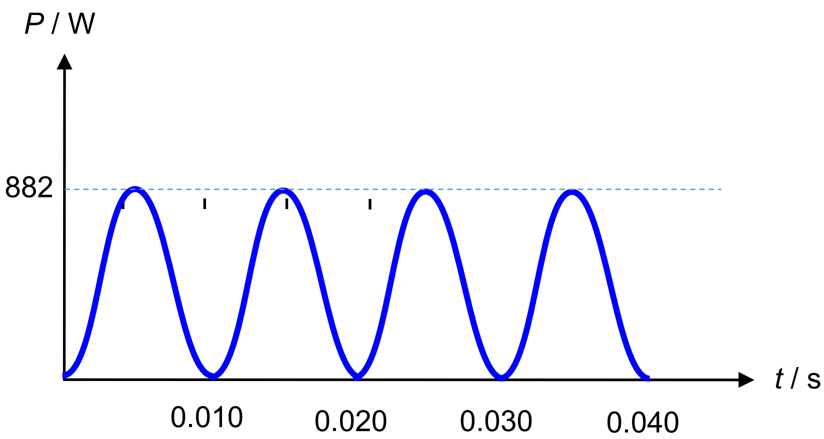
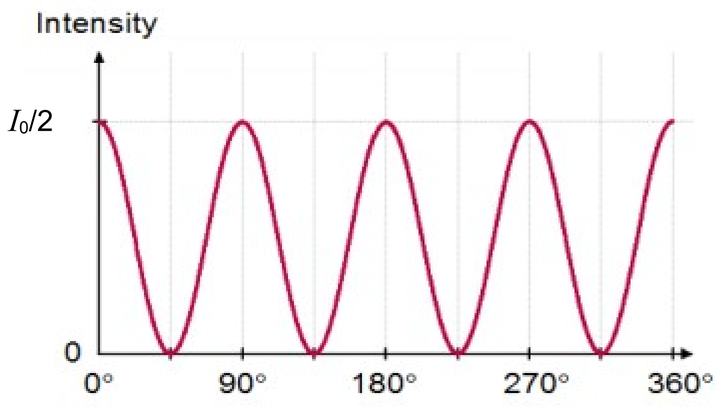
			$= 2.9 \text{ rad s}^{-1}$	
		(ii)	$\omega^2 = \dfrac{A\rho g}{M}$ $2.9^2 = \dfrac{(4.5 \times 10^{-4})\rho(9.81)}{(0.17)}$ $\rho = 323.86 = 320 \text{ kg m}^{-3}$	1 1
		(iii)	$v_0 = \omega x_0$ $v_0 = (2.9)(0.03)$ $= 0.087 \text{ m s}^{-1}$	1 1

7	(a)	(i)	From definition, $V = \dfrac{W}{Q} \Rightarrow W = VQ$	1
		(ii)	From definition of work, $W = Fd$	1
	(b)		From $VQ = Fd$, we have Electric field strength (force per unit charge) = $\dfrac{F}{Q} = \dfrac{V}{d}$ (potential gradient since the potential changes linearly with distance between the plates)	1 1
	(c)	(i)	$(82.4 – 82.0) \times 10^{-3} \times 9.81 = 3.9 \times 10^{-3}$ N	1
		(ii)	• The current (flow) in the rod produces magnetic field around it which interacts with the permanent field of the U-shaped magnet. • Due to the interaction, a downward force acts on the magnet while at the same time as a result of Newton's third law, an upward force acts on the rod. • The rod is fixed but the magnet (or balance) is moveable and so this additional force is recorded. • a correct reference to Fleming's LHR and Newton's 3rd Law Alternative: When a current flows in the rod placed in a B-field, a magnetic force is experienced by the rod [1] By N3L, an equal and opposite force is exerted on the magnet [1]	1 1
		(iii)	**1.**	

			 The force on the U-shaped magnet is inwards (into the plane of the paper) and so the force on the rod must be outwards (out of the plane). Based on Fleming's Left Hand Rule, the magnetic field is pointing vertically upwards. • arrow from lower to upper magnetic pole or • lower pole marked as the North pole / upper pole labelled South	1
		(iii)	**2.** Uses L = 6.7 cm Recall and correctly substitute in $F = BIL$ $I = \frac{F}{BL} = \frac{(3.9 \times 10^{-3})}{(28.6 \times 10^{-3})(6.7 \times 10^{-2})}$ = 2.03 A	1 1
			3. With the current reversed, the forces are attractive (the magnet is partially supported by the magnetic force due to the current in the rod). Thus, the reading is reduced, New reading = (82.0 – 0.4) = 81.6 g	1

8	**(a)**		The steady direct voltage value which provides the same power / energy dissipation as the alternating voltage.	**1**
	(b)		$\langle V^2 \rangle = [(4^2 \times 2) + (2^2 \times 4)] / 10$ $= 4.8$ $V_{rms} = \sqrt{4.8}$ $= 2.19 = 2.2$ V Mean power = $V_{rms}^2/R = 2.19^2 / 25 = 0.192$ W	**1** **1** **1**
	(c)		For a given power, higher voltage means lower current in cable. Lower current in cable will result in lower power lost in cable.	**1** **1**

	(d)	**(i)**	$\frac{V_s}{V_P} = \frac{N_s}{N_P}$ $V_s = 70 \times 15 = 1050$ V	**1**

		(ii)	 Labelling of correct P_o value – 1 mark $P_o = V_o^2 / R = (\sqrt{2} \times 1050)^2 / 2500 = 882$ W Correct shape – 1 mark	2
9	(a)	(i)	Wavelength λ = 2.4 cm Path difference Δx = 0.4 cm $\frac{\Delta x}{\lambda} \times 2\pi = \frac{0.4}{2.4} 2\pi = \frac{\pi}{3} = 1.05 rad$ The waves are out of phase with … phase difference = 60° or $\pi/3$ rad Unit : degree or rad depending on the value stated for phrase difference	 1 1
		(ii)	From Fig. 9.1, we can see that any point on one wave has a constant separation with a point of the same phase on the other wave, hence the two waves are **always** in constant phase difference or have a constant phase relation. Therefore, they are said to be coherent.	1 1
	(b)	(i)	$I_0/2$ [When an **unpolarised** light passes through a polariser of any axis, the intensity will be halved]	1
		(ii)	$I_0/2 \cos^2(\phi)$	1
		(iii)		

			1m for correct shape 1m for correct angle for each cycle 1m for correct max intensity value	
	(c)	(i)	$\sin\theta_1 = \lambda/d$ $= (590 \times 10^{-9})/(0.2 \times 10^{-3}) = 2.95 \times 10^{-3}$ $\theta_1 = 2.95 \times 10^{-3}$ rad	 1 1
		(ii)	$\theta_2 = 3 \times 2.95 \times 10^{-3} = 8.85 \times 10^{-3}$ rad	1
		(iii)	Width $= 2 \times 2.95 \times 10^{-3} \times 0.75$ $= 4.4$ mm	1 1
		(iv)	For patterns to be just resolved, central maximum of one beam must lie on the first minimum of the other (Rayleigh's criteria) angle $= 2.95 \times 10^{-3}$ rad	1 1
	(d)	(i)	$x = \dfrac{\lambda D}{a}$ $\lambda = \dfrac{ax}{D}$ $= \dfrac{(2.5\times10^{-3})(0.45\times10^{-3})}{1.83}$ $= 6.15\times10^{-7}\,m = 615$ nm	 1 1
		(ii)	**Advantage**: **More light is able to pass through** and thus the **interference fringes** will be brighter (more contrasting), and more easily observed. **Disadvantage**: The light passing through each slit **diffracts (spread out) less**, hence the **interference pattern formed will cover a smaller area** on the screen. In other words, there will be **fewer interference fringes that can be observed**.	1 1

10	(a)	(i)	The rate of decay is not dependent on physical conditions like temperature, pressure or chemical reactions	1
		(ii)	It is impossible to state exactly which nucleus or when a particular nucleus will disintegrate.	1
	(b)	(i)	$\Delta X/\Delta t$ (Refer to definition of activity)	1

		(ii)	$\Delta X/X$ (Number of nuclei that have decayed divided by total number of nuclei initially gives the probability of decay)	1
		(iii)	$\frac{(\frac{\Delta X}{X})}{\Delta t}$ (Decay constant is the probability per unit time)	1
	(c)	(i)	$\frac{A}{4\pi(0.400)^2}\times(5.0\times10^{-4}) = 250$ $A = 1.0\times10^{6}\ \text{s}^{-1}$	1 1
		(ii)	135 s is equivalent to 3 half-lives Thus, initial activity = $2^{3}(1.0\times10^{6})$ Using $A = \lambda N$, The initial number of atoms = $2^{3}(1.0\times10^{6}) / (0.693/45)$ $= 5.2\times10^{8}$	1 1
		(iii)	The result obtained is an over-estimation [1]. This is because there may be background radiation present [1]. Hence, the activity due to the source is less than that detected and thus the true initial number of atoms should be less [1].	
		(iv)	Since β-emissions comprises moving electrons, their path of travel can be deflected in a magnetic field.	1
	(d)	(i)	A large or heavy unstable nucleus splits into two or more smaller nuclei. This process is brought about by neutron bombardment of the nucleus.	1 1
		(ii)	This process may release energy when the binding energy per nucleon increases after the process.	1
		(iii)	1.	1
			2. Binding energy per nucleon /MeV When the binding energy per nucleon is low, it takes less energy to remove a nucleon from the nucleus.	1
		(iv)	Loss in energy = $3.1\times10^{-28}\times c^{2} = 2.79\times10^{-11}$ J So, one uranium-235 nucleus disintegrates with the release of 2.79×10^{-11} J of energy Let N be the number of uranium-235 nuclei that release 100 GeV of	1

Nucleon number

Fig. 10.1

			energy. Then, no. of nuclei required = $100 \times 10^{9} \times 1.6 \times 10^{-19} / 2.79 \times 10^{-11} = 570$	**1**