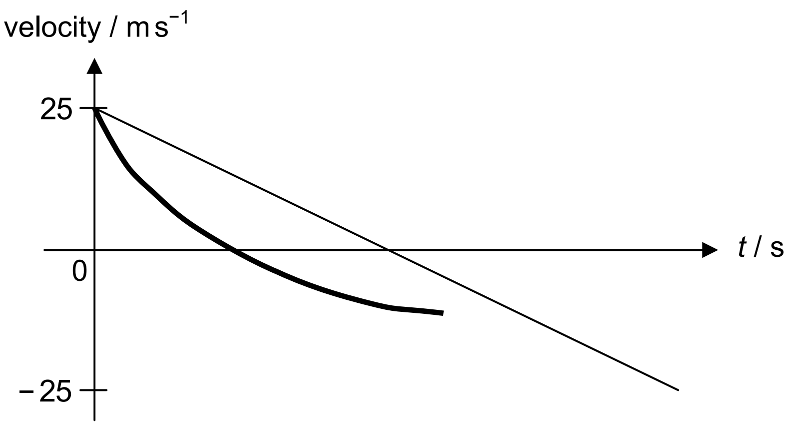
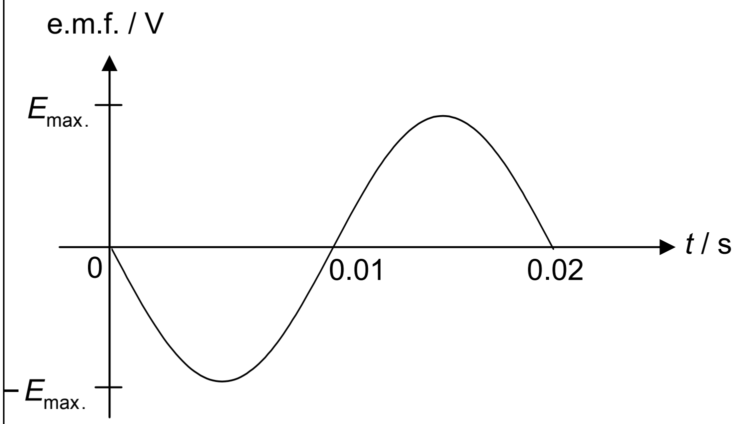
Answers to 2013 JC2 Preliminary Examination Paper 3 (H2 Physics)

Suggested Solutions:

No.	**Solution**
1(a)(i)	Let t be the time taken for the ball to reach the maximum height. The gradient of the v−t graph gives the acceleration, which is –9.81 m s^{-2} because the ball is falling freely. $-9.81 = \frac{0-25}{t-0}$ $t \approx 2.5$ s The time taken is 2.5 s.
1(a)(ii)	The area under the v−t graph gives the displacement. $s = \frac{1}{2} \times 2.5484 \times 25$ $s \approx 32$ m The maximum height is 32 m.
1(b)(i)	
1(b)(ii)	The ball will experience air resistance and weight in the same direction. Therefore, the <u>net downward acceleration is larger</u> and the <u>time taken will be shorter</u> to reach a <u>smaller maximum height</u>.
2(a)	The principle of superposition states that <u>when two or more travelling waves of the same type meet at a point in space</u>, the <u>resultant displacement</u> at that point is the <u>vector sum</u> of the displacements that the waves would separately produce at that point.

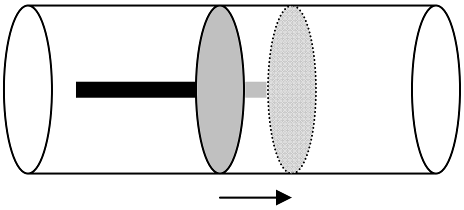
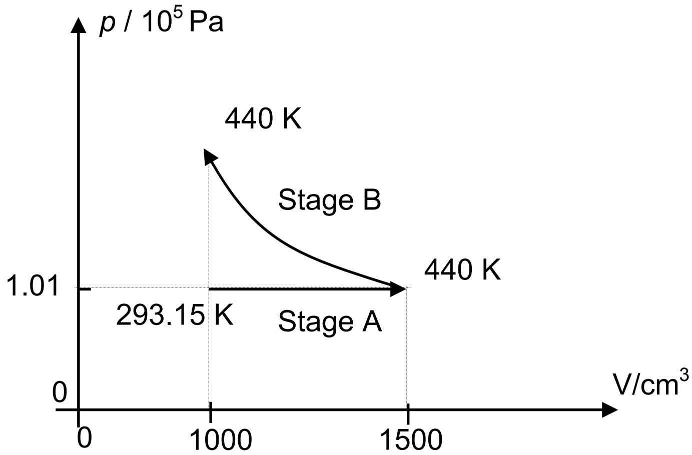
2(b)(i)	Path difference $= 2 \times 0.020$ $= 0.040$ m
2(b)(ii)	Path difference = $\frac{\lambda}{2}$ $\lambda = 2 \times 0.040$ $= 0.080$ m $v = f\lambda$ $= 4000\ (0.080)$ $= 320\ \text{m s}^{-1}$
2(b)(iii)	The sound waves from path LXM and LYM travel in the opposite directions and meet. Since both waves are of equal amplitude, frequency and speed, they superpose and interfere to form a stationary wave.
3(a)	Potential difference = 2.0 V
3(b)	Using $V = IR$, $2.0 = (1.2 \times 10^3)\ I$ $I = 1.67 \times 10^{-3}$ A $R = \frac{V}{I} = \frac{7.0}{1.67 \times 10^{-3}}$ = 4200 Ω or 4.2 kΩ
3(c)	From Fig. 3.1, light intensity = 24 W m^{-2}
3(d)	Length of strip, $\ell = (10 \times 5.0 \times 10^{-3}) + (10.0 \times 10^{-3}) = 0.060$ m Using $R = \frac{\rho \ell}{A}$, $\rho = \frac{RA}{\ell} = \frac{4200 \times 5.0 \times 10^{-7}}{0.060} = 3.5 \times 10^{-2}\ \Omega\text{m}$
3(e)	Larger changes in R at low light intensities, resulting in larger changes in the p.d. across the LDR. Hence greater sensitivity of the LDR at low light conditions, which is used to control the brightness of the lamp.

4(a)	
4(b)(i)	$\lvert E\rvert = \left\lvert -\frac{d\Phi}{dt}\right\rvert$ $= \left\lvert -\frac{0 - NBA\cos\theta}{\Delta t}\right\rvert$ $= \left\lvert -\frac{0-\left(100\times 0.35\times 2.5\times 10^{-2}\right)}{0.005}\right\rvert$ $= 175\ \text{V}$ The average e.m.f. induced is 175 V.
4(b)(ii)	As the coil turns, the flux linkage through the coil decreases. Hence, the induced magnetic field should be in the same direction as the external field. Using right-hand grip rule, the direction of the induced current is clockwise, which means that B is at a higher potential than A.
4(c)	The maximum torque on the coil occurs when the plane of the coil is vertical. Maximum torque experienced by the coil, $\tau = F_B \times d$ $= NBIL \times d$ $= NBIA$ $= 100\times 0.35\times 1.2\times 2.5\times 10^{-2}$ $= 1.05\ \text{N m}$
5(a)	Threshold frequency f_o, refers to the minimum frequency of the illuminating source that will cause a photoelectron to be ejected.
5(b)(i)	Energy of a photon, $E = \frac{hc}{\lambda} = \frac{\left(6.63\times 10^{-34}\right)\left(3\times 10^{8}\right)}{450\times 10^{-9}} = 4.4\times 10^{-19}\ \text{J}$

5(b)(ii)	Power incident on metal, $P = (2.7 \times 10^{3})(3.0 \times 10^{-4}) = 0.81$ W $P = \left(\frac{N}{t}\right)E$ $\Rightarrow \frac{N}{t} = \frac{P}{E} = \frac{0.81}{4.4 \times 10^{-19}} = 1.8 \times 10^{18}\ \text{s}^{-1}$
5(b)(iii)	Max. K.E. = $eV_s = (1.6 \times 10^{-19})(1.6) = 2.6 \times 10^{-19}$ J Applying Einstein Photoelectric equation, Work function, $\phi = hf - \text{max. K.E.} = 4.4 \times 10^{-19} - 2.6 \times 10^{-19} = 1.8 \times 10^{-19}$ J Threshold wavelength, $\lambda = \frac{hc}{\phi} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{1.8 \times 10^{-9}} = 1.1 \times 10^{-6}$ m
6(a)	The gravitational field strength *g* at a point is defined as the gravitational force per unit mass acting at that point.
6(b)	At the North Pole, gravitational force produces the acceleration due to free fall. On the equator, since the Earth is rotating, part of the gravitational force on a mass supplies the centripetal force for the mass to move in circular motion. As such, the acceleration due to free fall at the equator is slightly lower than that at the North Pole.

6(c)(i)	For circular motion, centripetal force = gravitational force $F_c = F_g$ $mr\omega^2 = \frac{GMm}{r^2}$ $\frac{4\pi^2}{T^2} = \frac{GM}{r^3}$ $T^2 = \frac{4\pi^2 r^3}{GM}$ $T^2 = \frac{4\pi^2 r^3}{6.67\times10^{-11}(6.0\times10^{24})}$ $T = 3.1\times10^{-7} r^{\frac{3}{2}}$ $\therefore A = 3.1\times10^{-7}\text{ s m}^{-\frac{3}{2}}$ $\therefore n = \frac{3}{2}$
6(c)(ii)	$r = \left(\frac{T}{A}\right)^{\frac{2}{3}}$ $= \left(\frac{24\times3600}{3.1408\times10^{-7}}\right)^{\frac{2}{3}}$ $= 4.23\times10^{7}\text{ m}$ Distance from surface of Earth $= 4.23\times10^{7} - 6.4\times10^{6}$ $= 3.6\times10^{7}\text{ m}$
6(c)(iii)	Total energy of satellite = GPE + KE $= \frac{1}{2}mv^2 + \left(-\frac{GMm}{r}\right)$ $= \frac{1}{2}m\left(\sqrt{\frac{GM}{r}}\right)^2 - \frac{GMm}{r}$ $= -\frac{GMm}{2r}$ $= -\frac{6.67\times10^{-11}(6.0\times10^{24})(1500)}{2(4.2287\times10^{7})}$ $= -7.096\times10^{9}\text{ J}$ $\approx -7.1\times10^{9}\text{ J}$
6(c)(iv)	Energy at surface of Earth = GPE + KE $= -\frac{GMm}{r_{Earth}} + 0$ $= -\frac{6.67\times10^{-11}(6.0\times10^{24})(1500)}{(6.4\times10^{6})}$ $= -9.3797\times10^{10}\text{ J}$

	Energy required $= -7.096\times10^{9} - (-9.3797\times10^{10})$ $= 8.6701\times10^{10}$ J $\approx 8.7\times10^{10}$ J
6(c)(v)	The force of attraction to the Earth is towards its centre so the circular orbit must be centred on the Earth's centre. Any orbiting satellite would satisfy this condition but would have varying latitude and will not be geostationary unless it is over the Equator.
6(c)(vi)	When the satellite is under the sun, the solar cells are used to power the equipment as well as to recharge the batteries. When the satellite is not in the sunlight, the rechargeable batteries are used instead.
6(c)(vii) 1.	More negative.
6(c)(vii) 2.	Total Energy $= -\dfrac{GMm}{2r}$ Since total energy is more negative (i.e. magnitude has increased) and is inversely proportional to the radius of orbit, this means the radius of orbit has decreased.
7(a)(i)	The specific heat capacity *c* of a substance is defined as the heat (thermal energy) per unit mass required to raise the temperature of the substance by one unit of temperature.
7(a)(ii)	The same steady inflow and outflow temperatures are maintained for both experiments so that the rate of heat lost is the same in both experiments so that it can be taken into account in the conservation of energy equations when calculating the specific heat capacity.
7(a)(iii)	$V_1 I_1 = \dfrac{m_1}{t_1} c\Delta\theta + \dfrac{H_1}{t_1}$ -------------- (1) $V_2 I_2 = \dfrac{m_2}{t_2} c\Delta\theta + \dfrac{H_2}{t_2}$ -------------- (2) Since $\dfrac{H_1}{t_1} = \dfrac{H_2}{t_2}$, $c = \dfrac{(V_2 I_2 - V_1 I_1)}{(\frac{m_2}{t_2} - \frac{m_1}{t_1})\Delta\theta} = \dfrac{(37.8-25.2)(60)}{(0.232-0.150)(17.4-15.2)}$ $= 4190$ J $kg^{-1} K^{-1}$

7(b)	 Work done = force × distance moved = (pressure × cross-sectional area) × distance moved = pressure × change in Volume
7(c)(i)1.	Using $pV = nRT$ Since pressure is constant, V is proportional to T for a fixed mass of gas. $V_1 / V_2 = T_1 / T_2$ T_2 = (1500/1000) × (273.15 + 20) = 440 K
7(c)(i)2.	Work done by gas = $p \times \Delta V$ = $1.01 \times 10^5 \times (0.0015 - 0.0010)$ = 51 J
7(c)(i)3.	No. of moles = $1.01 \times 10^5 \times 0.0010 / 8.31 \times 293.15$ = 0.0415 moles
7(c)(i)4.	Heat supplied = $mc\Delta\theta$ = (no. of moles × molar mass) × 1030 × (440 − 293.15) = 0.0415 × 0.028 × 1030 × (440 − 293.15) = 176 J
7(c)(ii) 1.	Since the change is isothermal, i.e. <u>no change in temperature,</u> then there is <u>no change in internal energy</u> in stage B. This is because internal energy of an ideal gas is <u>dependent on temperature</u> only.
7(c)(ii) 2.	
7(c)(iii)	Since there is no change in internal energy in Stage B, the change in internal energy at the end of the 2 stage change is = change in internal energy in Stage A. By the first law of thermodynamics, the change in internal

	energy in Stage A is given by $\Delta U = Q + W$ $= +176 + (-51)$ $= \underline{+125 \text{ J}}$
8(a)(i)	Nuclear fission is the <u>*splitting* of a large nucleus into two or more smaller nuclei,</u> with the <u>emission of a few neutrons and/or other radiations</u>.
8(a)(ii)	Number of protons $= 92 - 57 = 35$ Number of neutrons $= 236 - 2 - 139 - 35 = 60$
8(b)(i)	Gamma radiation
8(b)(ii)	A slow moving neutron can be captured by the Uranium nucleus as compared to a fast moving neutron and so this will enable the fission to occur.
8(b)(iii)	$200\,\text{MeV} = 200 \times 10^{6} \times 1.6 \times 10^{-19}$ $= 3.2 \times 10^{-11}\text{J}$
8(b)(iv) 1.	total power generated $=$ number of processes per unit time $\times$ energy in each process $3065 \times 10^{6} = \frac{N}{t} \times 3.2 \times 10^{-11}$ $\frac{N}{t} = 9.58 \times 10^{19}$
8(b)(iv) 2.	waste heat produced in 1 s $= 0.7 \times 3065 \times 10^{6}$ $= 2.15 \times 10^{9}$ J
8(b)(v)	$0.97 \times (\text{waste heat in 1 s}) = (\text{mass of water in 1 s}) \times c \times \Delta\theta$ $0.97 \times 2146 \times 10^{6} = m \times 4200 \times 3.5$ $m = 1.416 \times 10^{5} = 1.42 \times 10^{5}$ kg
8(c)(i)	The decay constant of a radioactive material is the <u>probability of decay</u> of a nucleus <u>per unit time</u>.
8(c)(ii)	$\lambda = \frac{\ln 2}{87.7 \times 365 \times 24 \times 60 \times 60}$ $= 2.51 \times 10^{-10}\ \text{s}^{-1}$
8(c)(iii)	$A_o = \lambda N_o = 2.51 \times 10^{-10} \times 1.74 \times 10^{25}$ $= 4.36 \times 10^{15}$ Bq
8(c)(iv)	$A = A_o e^{-\lambda t} = 4.36 \times 10^{15} \times e^{-7.90 \times 10^{-3} \times 10}$ $= 4.03 \times 10^{15}$ Bq