2013 H2 Physics Prelim 2 Exam – Paper 3 Solutions

1	(a)	(i)	The reaction force must have a horizontal component because the horizontal component of the tension is unbalanced (or needs to be balanced by another horizontal force). It must also have a vertical force to produce an anti-clockwise moment in order to balance the clockwise moment caused by the tension when moment is taken about his C.G.. OR since all forces must pass through a common point, the reaction force from the wall on the person is at an angle to the horizontal. Hence there are horizontal and vertical components.	[B1] [B1]
		(ii)	The reaction force must point about northwest, towards the intersection of the weight and tension.	[B1]
	(b)		Equilibrium of horizontal forces: $(F_R)_X$ = 610 sin20° (208.6 N leftward) Equilibrium of vertical forces: $(F_R)_X$ + 610 cos20° = 590 (16.79 N upward) F_R = squareroot $[(F_R)_X^2 + (F_R)_Y^2]$ = 209.3 N Angle with vertical = $\tan^{-1}[(F_R)_X / (F_R)_Y]$ = 85.4°	[M1] [M1] [A1] [A1]
2	(a)	(i)	$v = f\lambda$ $0.90 = f(0.30)$ f = 3.0 Hz	
		(ii)	$f = \dfrac{1}{2\pi}\sqrt{\dfrac{28}{m}}$ m = 0.0788 kg	
	(b)	(i)	Amplitude of the vertical oscillations will also increase. [A1] **Driving force is larger** due to the larger amplitude of wave, OR more energy transfer. [M1]	
		(ii)	wavelength of wave increases and since the speed remains the same, by $v = f\lambda$ frequency of wave will decrease. [M1] (wavelength has increased, driving frequency will decrease, for the same speed. Since driving frequency is not equal to natural frequency, **amplitude will decrease. [A1]** A.k.a. no more resonance)	
		(iii)	Damping force increases [M1] → amplitude decreases [A1]	
3	(a)		The graph in Fig. 3.1 **curves towards the current axis** Hence the **ratio of V to I will decreases** with increasing voltage OR the line drawn from origin to a point on the curve becomes gentler as voltage increases. Hence the ratio of V to I, which is the inverse of the gradient of this line, decreases.	[B1] [B1] [B1] [B1]
	(b)		The semiconductor has a band structure with a small band gap between the fully-filled valence band and the totally-unfilled conduction band at zero kelvin. With an increase in temperature, some electrons from the valence band can	 [B1]

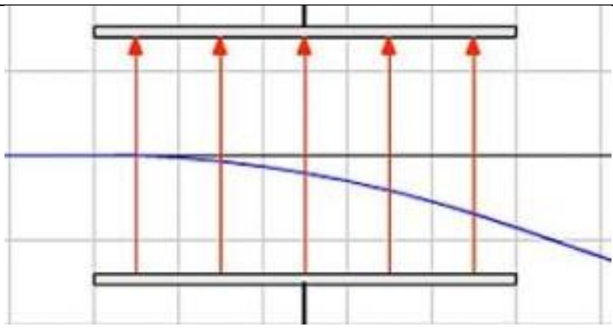
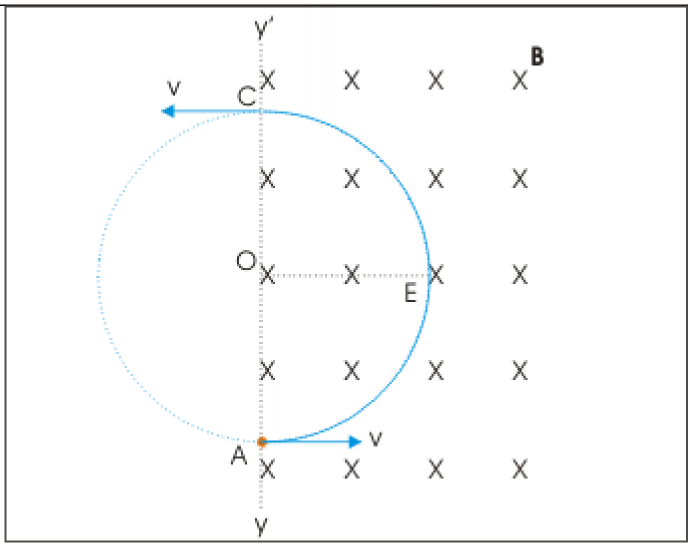
<table>
<tr><td></td><td></td><td></td><td>easily gain enough thermal energy to promote to the conduction band via the small gap.
The electrons in the conduction band and holes in valence band behave as mobile charge
carriers, increasing the number of <u>mobile positive and negative charge carriers</u>.</td><td>[B1]

[B1]</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>Current through X = 90 – 47 = 43 mA
From Fig. 3.1, p.d. across X = 6.2 V</td><td>[C1]
[A1]</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>p.d. across R and X = p.d. across 180 Ω resistor = I x R
= 47 x 10^{-3} x 180 = 8.46 V
p.d. across R = p.d. across R and X – p.d. across X = 8.46 – 6.20 = 2.26 V
R = V / I = 2.26 / 0.043 = 52.6 Ω.</td><td>[C1]

[A1]</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>Since the voltage across the 180 ohm resistor is less than 9 V (8.46V), this means that there is internal resistance in the cell.</td><td>[B1]</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>(a)</td><td></td><td>
<table>
<tr><th>A single change made to the experiment</th><th>Minimum wavelength, λ_o</th><th>Wavelengths of K spectra lines</th></tr>
<tr><td>V is increased</td><td>Decrease</td><td>Unchanged</td></tr>
<tr><td>I is decreased</td><td>Unchanged</td><td>unchanged</td></tr>
<tr><td>M is replaced with another metal of a lower mass number</td><td>Unchanged</td><td>increase</td></tr>
</table>
All 6 blanks correct – 3M
All 4 blanks correct – 2M
Any 2 blanks correct or more – 1M</td><td></td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>The minimum wavelength is emitted as a photon in a single collision by the electron which is all its kinetic energy. [B1]
eV = hc / λ_o
λ_o = hc / eV
= $(6.63 \times 10^{-34})(3 \times 10^{8}) / (1.60 \times 10^{-19})$ V [M1]
= 1.24×10^{-6} / V
= 1240 nm / V [A1 for conversion to nm]</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>λ_o = 1240 nm / V
= 1240 nm / 50 x 10^{3} V
= 0.0248 nm [A1]</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>(a)</td><td>(i)</td><td>curve is not smooth, fluctutations, etc</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Curve is same shape or same half life,, not affected by temperature etc</td><td></td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>$\lambda = \ln 2/t_{1/2} = 0.193\ \text{day}^{-1} = 2.23 \times 10^{-6}\ \text{s}^{-1}$</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$N = \{(2.24 \times 10^{-3})/224\} \times 6.02 \times 10^{23}$
$= 6.02 \times 10^{18}$</td><td></td></tr>
</table>

			Acitivity = $\lambda N = 2.23 \times 10^{-6} \times 6.02 \times 10^{18}$ $= 1.3 \times 10^{13}$ Bq	
		(iii)	$A = A_0e(-\ln 2.t/T)$ $0.1 = \exp(-\ln 2.n)$ $n = 3.32$	
6	(a)		It has 2 protons and two neutrons.	
	(b)		This is a fission process. The reactants have a smaller mass as compared to the products, hence with reference to the B.E per nucleon curve, the products will have a larger B.E. per nucleon and hence a greater stability. This is a fusion process [B1], because smaller nuclei fused to form a heavier nucleus. [B1]	
	(c)		Total rest mass of reactants = 13.9993 u + 4.0015 u = 18.0008 u Total rest mass of products = 16.9947 u + 1.0073 u = 18.0020 u Difference in rest mass = 18.0020 u – 18.0008 u $= 1.2 \times 10^{-3} \times 1.66 \times 10^{-27}$ $=1.992 \times 10^{-30}$ kg	
	(d)		$K.E_{min} = \Delta mc^2$ $= (1.992 \times 10^{-30})(3.0 \times 10^8)^2$ $= 1.7928 \times 10^{-13}$ J	
	(e)		Total initial momentum, $P_{T,I} = (3.0 \times 10^7)(13.993\ u) + 0$ Total final momentum, $P_{T,f} = (6.0 \times 10^7)(1.0073\ u) + (16.9957\ u)(v)$ By conservation of linear momentum, $P_{T,I} = P_{T,f}$ $(3.0 \times 10^7)(13.993\ u) + 0 = (6.0 \times 10^7)(1.0073\ u) + (16.9957\ u)(v)$ $v = 3.51 \times 10^6$ m s^{-1} Direction: Right	
	(f)	(i)	Momentum of a body is the <u>product of its mass and velocity</u>.	
		(ii)	By conservation of momentum, $0 = m_1v_1 - m_2v_2$ students must show understanding that both particles move off in opposite directions $\Rightarrow \frac{v_1}{v_2} = \frac{m_2}{m_1}$	
		(iii)	1. $\frac{1}{2}(6.7 \text{ x } 10^{-27})v^2 = 1.2 \text{ x } 10^{-14}$ $\Rightarrow v = 1.9 \text{ x } 10^6 \text{ m s}^{-1}$	
		(iii)	2. $v/1.9 \text{ x } 10^6 = (6.7\text{x}10^{-27})/(4.0 \text{ x } 10^{-25} - 6.7 \text{ x } 10^{-27})$ [C1] ➔ $v = 3.3 \text{ x } 10^4$ ms^{-1} [A1] <u>Alternative method:</u>	

			$(mv)_{recoilingnucleus} = (mv)_{\alpha}$ $(4.0 \times 10^{-25} - 6.7\times10^{-27})v = 1.3 \text{ x } 10^{-20}$ $\Rightarrow$ v = $3.3 \text{ x } 10^{4}$ m s^{-1}	
		(iii)	3. The alpha-particle has energy less than the energy of the potential barrier of the nucleus. [**B1**] However, since its wave function is non-zero beyond the barrier (outside the nucleus), it has a finite probability of decaying/emitting/escaping from the nucleus. [**B1**]	
7	(a)		It is the work done per unit positive charge [M1] in moving a charge from infinity to the point. [A1]	
	(b)	(i)	$F = \frac{Q_1Q_2}{4\pi\varepsilon r^2}$ $= \frac{(3.6\times10^{-9})^2}{4\pi\varepsilon(0.30)^2}$ $= 1.29\times10^{-6}N$ 1 mark for the substitution 1 mark for the answer.	
		(ii)	The total potentials at P and Q are the same. [M1] Work done is the product of charge and potential difference between P and Q. [M1]	
		(iii)	At P, $PE = \frac{Q_1}{4\pi\varepsilon r_1} + \frac{Q_2}{4\pi\varepsilon r_2}$ $= \frac{(3.6\times10^{-9})}{4\pi\varepsilon(0.075)} + \frac{(3.6\times10^{-9})}{4\pi\varepsilon(0.225)}$ $= 575.5JC^{-1}$ 1 mark for substitution 1 mark for answer	
		(iv)	At the midpoint of **AB**, find potential (1M) $PE = \frac{Q_1}{4\pi\varepsilon r_1} + \frac{Q_2}{4\pi\varepsilon r_2}$ $= 2\times\frac{(3.6\times10^{-9})}{4\pi\varepsilon(0.15)}$ $= 431.6JC^{-1}$ Work done = q ΔV = $(-1.6 \text{ x } 10^{-19})$ (575.5 –(431.6)) [M1] = – 2.30 x10^{-17} J [A1]	
	(c)	(i)	x = 18.0 cm [A1]	
		(ii)	The direction of the electric field is the negative potential gradient. It is in the direction from positive to negative charge. OR direction of field points towards direction of decreasing potential. [B1]	

			The electric field is directed from A to B. [B1]	
		(iii)	At x = 18 cm, $0 = \dfrac{Q_1}{4\pi\varepsilon r_1} + \dfrac{Q_2}{4\pi\varepsilon r_2}$ $0 = \dfrac{(3.6\times10^{-9})}{4\pi\varepsilon(0.18)} + \dfrac{Q}{4\pi\varepsilon(0.12)}$ $Q = -2.4\times10^{-9}C$ 1 mark for the equation (sum of potentials equal to 0) 1 mark for substitution 1 mark for the answer.	
		(iv)	The field strength is the negative potential gradient or the gradient of the graph. [B1] Field strength is the highest at the steepest gradient at point x = 27 cm. [B1] The electric force is the product of the charge and the gradient of the graph. [B1] Hence, the force is maximum at x = 27 cm. [A0]	
8	(a)	(i)	 The particle follows a parabolic path.	
		(ii)	 The particle follows a circular path.	
	(b)	(i)	When electron is accelerated to the higher potential of 0 V, electron loses electric potential energy = eΔV	

			By conservation of energy, Gain in kinetic energy = loss in EPE [B1] ½ $(2.84 \times 10^{-26)} v^2 = (1.6 \times 10\text{-}19)(3000)$ $v = 1.83 \times 10^5$ m s^{-1} [A1]	
		(ii)	When the negative ions enter into the region of electric and magnetic fields, The ions experience a magnetic force to the left, [B1] if P2 is set to be positive, the ions can experience an electric force to the right. [B1] When the two forces balanced each other, the net force on the ions would be zero [B1] and the ions can pass through without being deflected.	
		(iii)	Magnetic force = electric force Bqv = eE $E = (0.83\ T)(1.83 \times 10^5\ m\ s^{-1}) = 1.53 \times 10^5\ V\ m^{-1}$	
	(c)	(i)	Out of the plane of the paper	
		(ii)	When the ions enter into the magnetic field, it experiences a magnetic force at right angles to the direction of motion of the ions. [B1] The magnetic force provides the centripetal force, changing the direction of velocity of the ions and keeping the speed constant. [B1]	
		(iii)	Magnetic force provides the centripetal force $Bqv = mv^2/ r$ [C1] r = mv/Bq [C1] Since the speed of the ions exiting point O have the same value, B is constant and charge the same, Radius is proportional to the mass *m* of the ions [C1] OA = 2(radius) is proportional to the mass *m* of the ions	
		(iv)	The larger the mass, the greater the distance OA, and we can distinguish the different ions.	
	(d)	(i)	for same specific charge, no change to the speed	
		(ii)	NO change, ions still pass through undeflected.	
		(iii)	No change, since radius is proportional to q/m.	