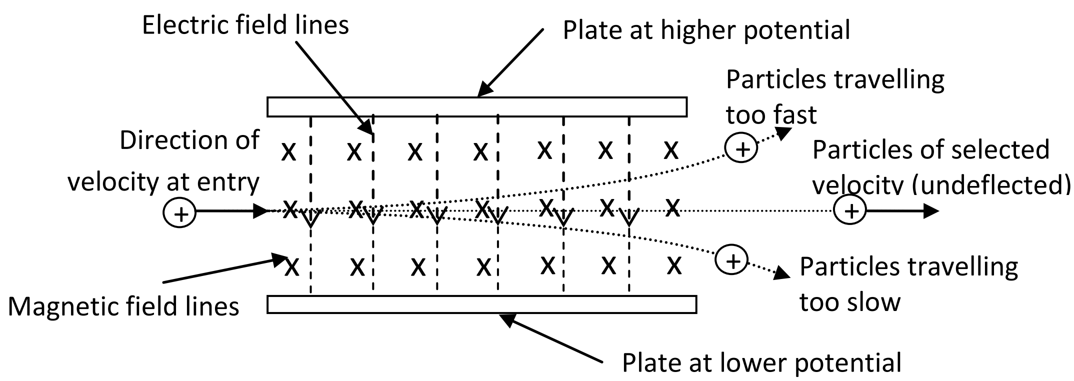
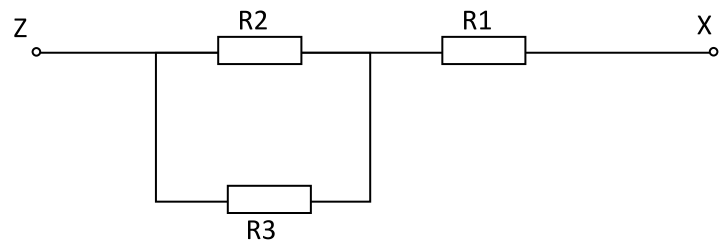
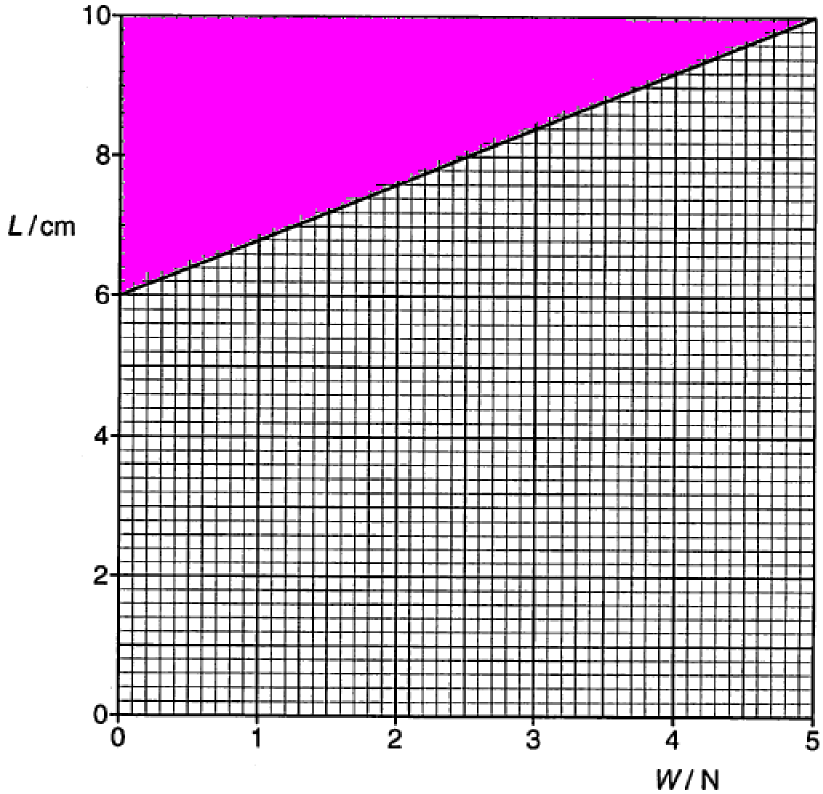
H2 Physics 9646 – Paper 3 (Worked Solutions)

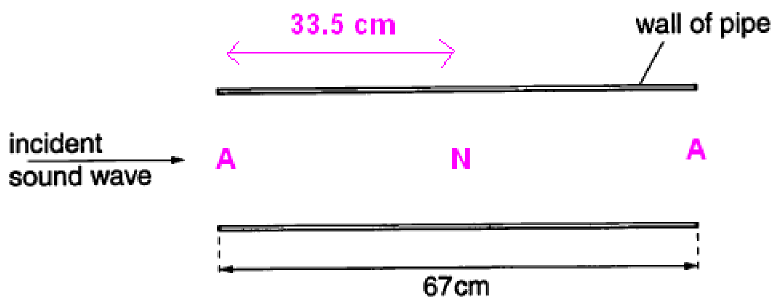
1	(a)		It is the thermal energy *absorbed* when a substance changes from liquid to vapour at constant temperature. Equivalently, it is the thermal energy *released* when a substance changes from vapour to liquid at constant temperature. *Examiner's report:* *A number of candidates confused latent heat with specific latent heat.* *The fact that it occurs at constant temperature must not be omitted.*
	(b)	(i)	So that heat loss to the environment may be accounted for. *Examiner's report:* *A number of candidates thought that heat loss will be eliminated in the experiment, rather than through calculations. These candidates were not awarded marks.*
		(ii)	Heat supplied by heater = Heat absorbed by water + Heat loss to environment (h) Pt = mL + h Sub in values from table: 140 (5 x 60) = 0.0141 L + h ----- (1) 95 (5 x 60) = 0.0082 L + h ----- (2) (1) – (2): 13500 = 0.0059 L $L = 2.2881 \times 10^{6}$ J kg^{-1} = 2290 J g^{-1}
2	(a)	(i)	The centripetal force on the ball is provided by both its weight (mg) and the tension exerted by the rod on the ball.
		(ii)	3mg
		(iii)	When the ball is vertically above C, $3mg = mv^2/r$ $v^2/r = 3g$ --- (1) Since ball's speed v is constant, When the ball is vertically below C, $T – mg = mv^2/r$ T – mg = 3mg T = 4mg
	(b)	(i)	From (a)(ii), Centripetal force = 3mg = $mr\omega^2$ $3(9.81) = 0.72\ \omega^2$ ω = 6.3934 = 6.39 rad s^{-1}
		(ii)	v = r ω = 0.72 x 6.3934 = 4.6032 = 4.60 m s^{-1}
	(c)	(i)	Gravitational potential energy is decreased but kinetic energy is constant. Hence work must be done to maintain constant kinetic energy.

			Examiner's report: *A common misconception was to state that work has to be done because the centripetal force has changed direction from being vertically upwards to vertically downwards. Note also that work done by centripetal force equals zero.*
		(ii)	By conservation of energy, Work done on ball = Loss in GPE = mg (2r) = 0.240(9.81)(2x0.72) = 3.39 J
3	(a)	(i)	It is a region in space where a body placed in it experiences a force, even though it may not be in direct contact with another body.
		(ii)	Field strength is related to the closeness of the lines of force.
	(b)	(i)	Mass
		(ii)	Positive charge
		(iii)	Force on a north pole *Not accepted: force on a moving charge. Note that he force on a moving charge is not in the direction of the field.*
	(c)		 Velocity selector makes use of a uniform electric field placed perpendicular to a uniform magnetic field. The relative orientation of the 2 fields is such that the charged particles experience a magnetic force and an electric force in opposite directions. For the undeflected particles, the two forces are equal in magnitude: Electric force = Magnetic force qE = Bqv where q is the charge and v is the selected velocity v = E/B Thus by adjusting the electric field strength (E) and magnetic flux density (B) to obtain the desired ratio E/B, the desired velocity may be selected.
4	(a)	(i)	When A is closed and B opened, Resistance between X and Y = R1 = 6Ω
		(ii)	When A is opened and B is closed, Resistance between X and Y = R1 + R2 = 10Ω R2 = 10-6 = 4Ω
		(iii)	When both A and B are opened, Resistance between X and Y = R1 + R2 + R3 = 12Ω R3 = 12-10 = 2 Ω

	(b)		 Resistance between X and Z $= (1/R2 + 1/R3)^{-1} + R1$ = 7.33Ω
5	(a)		It is the minimum energy required by an electron to escape from the surface of the metal.
	(b)		Energy of each photon = hc/λ $= (6.63\text{x}10^{-34})(3\text{x}10^{8})/(540\text{x}10^{-9})$ $= 3.6833\text{x}10^{-19}$ J = 2.30 eV Since each electron can only absorb 1 photon, the energy of the photon is insufficient to overcome the work function of the metal. Hence no electrons are emitted.
	(c)		Intensity determines the **rate** of arrival of photons at the surface and not the energy of individual photons. Since each electron can only absorb one photon, the electrons will still have insufficient energy to overcome the work function of the metal. Hence no electrons emitted. *Examiner's report:* *It is more accurate to say that intensity governs the **rate** of arrival of photons (or number of photons reaching the surfaced **per unit time**), rather than the number of photons.* *Candidates must also mention that energy of the photons remain unchanged.*
6	(a)		Force is a push or a pull, acting in a specific direction. *Examiner's report:* *Candidates should be reminded that force is a vector quantity and that, where a vector quantity is being defined, direction should be taken into consideration.*

	(b)	(i)	
		(ii)	E = work done on spring = (**average** force exerted on spring) x (total extension) Since the force varies linearly with extension, **Average** force = $\left(\dfrac{minimum force + maximum force}{2}\right)$ E = $\left(\dfrac{minimum force + maximum force}{2}\right)$ x (total extension) = $\left(\dfrac{0 + force\ per\ unit\ extension\ x\ maximum extension}{2}\right)$ x (total extension) = $\left(\dfrac{0+kx}{2}\right)x$ = $\frac{1}{2}kx^2$ *Examiner's report:* *Most answers referred to 'area under the graph'. It was expected that the starting point would be a statement that work done is the product of average force and extension.*
	(c)	(i)	From fig. 6.2, L = 9.2 cm Total length = 9.2 + 0.8 =10.0 cm
		(ii)	1. Magnitude of change in GPE = mg (0.0080) = (4.0) (0.0080) = 0.032 J

			2. $k = 5/(10 – 6) = 1.25$ N cm^{-1} = 125 N m^{-1} Magnitude of change in EPE $= ½ k(0.10 – 0.06)^2 – ½ k(0.092 – 0.06)^2$ = 0.036 J
		(iii)	Work done + decrease in GPE = Increase in EPE Work done = Increase in EPE – Decrease in GPE = 0.036 – 0.032 = 0.004 J
	(d)	(i)	Total energy = <u>0.004 J</u> *Check:* *This should correspond to the difference between the energy at the amplitude position and the energy at the equilibrium position. Note that the mass oscillates about the equilibrium position.* $½ k (0.010 – 0.06)^2 – ½ k (0.092 – 0.06)^2 – mg(0.0080) = 0.004$ J
		(ii)	1. $KE_{max} = ½ m v_o^2 = ½ (4.0/9.81) v_o^2$ KE_{max} = Total energy – EPE at equilibrium point $½ (4.0/9.81) v_o^2 = 0.004 – ½ k(0.092 – 0.06)^2$ $v_o = 0.140$ m s^{-1} 2. $v_o = ωx_o = (2πf) x_o = 2πf (0.0080)$ $0.140 = 2πf (0.0080)$ f = 2.79 Hz
	(e)		A spring with mass would increase the effective mass of the oscillating system. This will cause the frequency of oscillation to decrease. ($ω=\sqrt{(k/m)}$)
7	(a)		Progressive: energy is transferred from the source outwards, in the direction of wave travel Transverse: particles in the medium oscillate in a direction perpendicular to the direction of energy transfer, but is not displaced in the direction of wave travel.
	(b)		In an unpolarised transverse wave, the particles in the medium oscillate in multiple planes which are perpendicular to the direction of energy transfer. In a polarize transverse wave, the particles in the medium oscillate on one plane only out of all possible planes that are perpendicular to the direction of energy transfer.
	(c)	(i)	A
		(ii)	I
		(iii)	$I \alpha A^2$.
	(d)		A, I 0, 0 Acos60° = ½ A, ¼ I
	(e)	(i)	The principle of superposition states that if two or more waves of the <u>same kind</u> exist simultaneously at a point, the <u>resultant displacement</u> is the <u>vector sum</u> of the individual displacements due to the waves <u>at this point</u>.
		(ii)	The incident sound wave is <u>reflected at the opposite open end of the pipe</u>. <u>The incident wave and reflected wave superpose</u>. Since the two waves are of the <u>same nature, same frequency, same speed and have similar amplitude and are travelling in opposite</u>

			directions, the resultant wave formed is a stationary wave.
	(f)	(i)	 *Examiner's report:* *Candidates needed to be more precise in their answers. The antinodes should have been shown at the ends of the pipe (or just outside) and the node at the centre.*
		(ii)	$\lambda/2 = 0.67$ $\lambda = 1.34$ m $v = f\lambda = 250\ (1.34) = 335$ m s^{-1}
	(g)		Antinodes are actually outside the pipe rather than right at the ends of the pipe as the vibrations of the air molecules extend slightly beyond the end of the pipes. As such, the value 1.34 m is an underestimate of the actual wavelength of the sound wave. Hence speed v is also underestimated.
8	(a)	(i)	For an isolated system, total momentum is conserved. Take vectors to the right as positive. Total momentum before decay = Total momentum after decay $0 = (4u)(V) + (A - 4)u(-v)$ $(A - 4)v = 4V$
		(ii)	$\frac{\frac{1}{2}(4u)V^2}{\frac{1}{2}(A-4)uv^2} = \frac{4V^2}{(A-4)v^2}$ From (a)(i), $V/v = (A - 4) / 4$ Hence, $\frac{\frac{1}{2}(4u)V^2}{\frac{1}{2}(A-4)uv^2} = \frac{4V^2}{(A-4)v^2} = \frac{4}{(A-4)}\left(\frac{V}{v}\right)^2 = \frac{4}{(A-4)}\left(\frac{A-4}{4}\right)^2 = \frac{A-4}{4} = \frac{1}{4}A - 1$
	(b)	(i)	Energy released = (change in mass) c^2 = (mass of parent nucleus - mass of daughter nucleus - mass of alpha particle) c^2 = (211.9459 - 207.9374 - 4.0015)u c^2

			$= 0.007\ (1.66\text{x}10^{-27})(3.00\text{x}10^{8})^2$ $= 1.0458\text{x}10^{-12}$ J = 6.54 MeV
		(ii)	Energy is released as kinetic energy of the daughter nucleus and the alpha particle. KE of daughter nucleus + KE of alpha particle = 6.54 MeV KE of daughter nucleus = 6.54 MeV - KE of alpha particle From (a)(ii), $\frac{KE\ of\ alpha}{KE\ of\ daughter} = \frac{1}{4}A - 1$ $\frac{KE\ of\ alpha}{6.54\ MeV\ -\ KE\ of\ alpha} = \frac{1}{4}(212) - 1 = 52$ $KE\ of\ alpha = 340.08 - 52(KE\ of\ alpha)$ $53(KE\ of\ alpha) = 340.08$ $KE\ of\ alpha = 6.42\ MeV$
	(c)	(i)	Part of the energy released in the reaction may be in the form of gamma ray photon. Thus the kinetic energy of the products will be less.
		(ii)	The gamma ray photon released has momentum. The emission of the gamma ray photon is in a random direction. Apart from the scenario where the gamma ray photon is released in the same direction as the velocity of either the thallium nucleus or the alpha particle, the velocity of the thallium nucleus and alpha particle will not be in opposite directions if the total momentum is kept constant at zero.
	(d)	(i)	$t_{1/2}$ = (ln 2) / λ = (ln 2) / $(1.9\text{x}10^{-4})$ = 3600 s
		(ii)	2 hours = 2 x 3600 s = 2 half-lives Hence the number of bismuth-212 nuclei decrease to ¼ of its initial number. Each bismuth-212 nucleus decays into a thallium-208 nucleus. Hence it is expected that the total number of thallium-208 nuclei formed is (N – ¼ N = ¾ N). However, the thallium-208 nucleus is itself unstable and will decay to form another more stable daughter nucleus. Since thallium-208 nucleus has a relatively short half-life of $3.7\text{x}10^{-3}$ s, hence the number of thallium-208 nuclei in the sample would be much less than ¾ N. *Examiner's report:* *Candidates were asked to explain these observations. Many did not attempt to explain why the number of bismuth nuclei would be reduced to approximately ¼N.* *Many had the misconception that rate of disintegration of the thallium would be greater than that of the bismuth.*