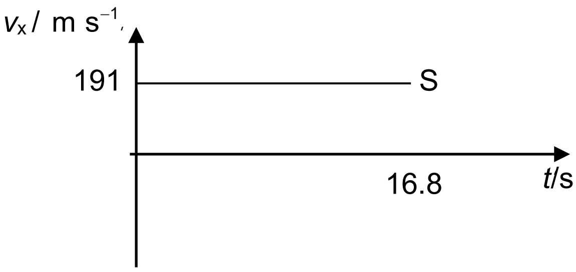
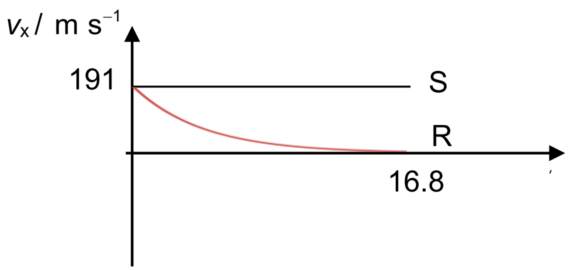
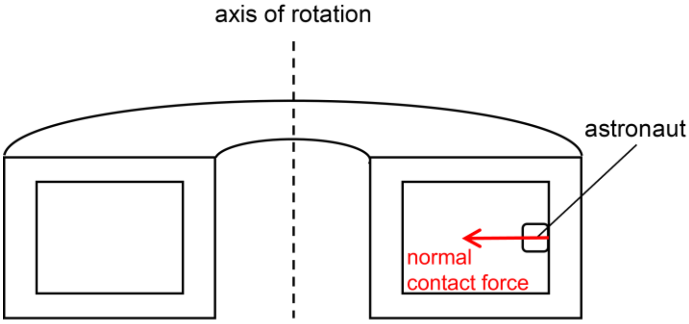
Qn	Suggested Solutions
1(a)(i)	$\Delta p = mv - mu$ $= 0.140\left(-4.0-(5.4)\right)$
	$\Delta p = -1.3$ N s
(ii)	$F = \left\lvert\dfrac{\Delta p}{\Delta t}\right\rvert = \dfrac{1.3}{0.04} = 32.5$ N
	$F = N - mg$ $32.5 = N - 0.14(9.81)$ $N = 34$ N
	By Newton's 3rd law, magnitude of the force exerted by the ball on the bar = magnitude of the force by the bar on the ball, *N*
(b)	Taking moments about B,
	$34(75) + 0.450(9.81)(25) = F_A(20)$
	$F_A = 133$ N

Qn	Suggested Solutions
2(a)(i)	$s_y = u_y t + \frac{1}{2} a_y t^2$ $x = 220\sin(30^\circ)(16.8) + \frac{1}{2}(9.81)(16.8)^2$
	$x = 3230$ m
(ii)	$v_x = u_x = 220\cos(30^\circ) = 190.5$ m s^{-1}
	$v_y = u_y + a_y t$ $v_y = 220\sin(30^\circ) + 9.81(16.8) = 274.8$ m s^{-1}
	$v = \sqrt{{v_x}^2 + {v_y}^2}$ $v = \sqrt{190.5^2 + 274.8^2}$ $v = 334$ m s^{-1}
	OR
	initial $E_k = \frac{1}{2} m (220)^2$
	loss in gravitational $E_P = mgh$ $= m(9.81)(3232)$
	final kinetic energy = loss in gravitational potential energy + initial kinetic energy $\frac{1}{2} m v^2 = m(9.81)(3232) + \frac{1}{2} m (220)^2$ $v = 334$ m s^{-1}
(iii)	
(b)	

Qn	Suggested Solutions
3(a)	
(b)(i)	Although the magnitude of the velocity is constant, its velocity is changing as the direction of its velocity is always changing.
	According to Newton's Second Law, the astronaut must experience rate of change of momentum / an acceleration and hence a resultant force.
	Both the acceleration and force act towards the centre.
(ii)	$g = 9.81 = \frac{v^2}{r}$ $r = \frac{100^2}{9.81} = 1019$
	$r = 1020m$

Qn	Suggested Solutions
4(a)	A polarised wave has its vibrations/oscillations occur in a single direction in a plane / restricted to one plane (axis) and perpendicular to the direction of transfer of energy/propagation.
(b)	Applying Malus' Law and assuming that the intensity of the polarised light after polaroid Q is I_0, $I = I_0 \cos^2 \theta$ $= I_0 \cos^2 (30°)$ $= 0.75 I_0$
	Since $I \propto A^2$ $\frac{I}{I_0} = \left(\frac{A}{A_0}\right)^2$ $\cos(30°) = \frac{A}{A_0}$ $A = 0.866 A_0$ $\approx 0.87 A_0$
(c)	It is the spreading of the wave into its geometrical shadow when it is incident on an aperture/opening or edge of an obstacle.
(d)(i)	$d \sin\theta = n\lambda$ $(3.4 \times 10^{-6}) \sin\left(\frac{16°}{2}\right) = \lambda$
	$\lambda = 4.73 \times 10^{-7}$ m $\approx 4.7 \times 10^{-7}$ m
(ii)	Blue/Indigo
(iii)	For an emerging beam to be observed on the screen, $\theta \leq 90°$ and hence $\sin\theta \leq 1$.
	Since $\sin\theta = \frac{n\lambda}{d}$, $\frac{n\lambda}{d} \leq 1$ $n \leq \frac{d}{\lambda}$ $n \leq \frac{3.4 \times 10^{-6}}{4.73 \times 10^{-7}}$ $n \leq 7.19$
	no. of emerging beams $= 7 + 7 + 1 = 15$
(iv)	Without the polaroids, the incident light intensity on the diffraction increases, so the diffraction maxima become brighter.
	The separation between maxima depends only on the wavelength of light and the line spacing of the grating, which are unchanged, so it remains the same.

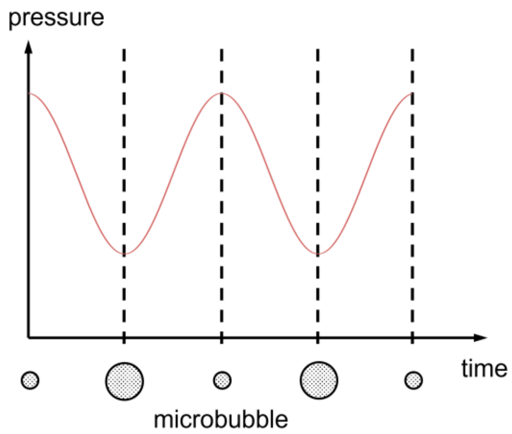
Qn	Suggested Solutions
5(a)	The resistance R of a circuit component is defined as the ratio of potential difference V across the conductor to current I flowing through the conductor.
(b)	current in series circuit $I = \dfrac{E}{R_{total}} = \dfrac{E}{A+B}$ pd across $A = IA = \left(\dfrac{E}{A+B}\right)A = \dfrac{A}{A+B}E$ (Shown)
(c)(i)	As the temperature of the thermistor is raised, its resistance will decrease.
	This will result in the combined resistance of the thermistor and the 4000 Ω resistance to decrease due to their parallel circuit arrangement.
	As a result, based on the potential divider principle, the potential difference across the 1500 Ω resistor will increase and hence, the voltmeter reading will increase.
(ii)	$\dfrac{1}{R} = \dfrac{1}{B} + \dfrac{1}{R_T}$ $\dfrac{1}{R} = \dfrac{1}{4000} + \dfrac{1}{2700}$ $R = 1612\ \Omega$
	$V = \dfrac{A}{A+R}E$ $V = \dfrac{1500}{1500+1612}(5)$
	$V = 2.41\text{ V}$
(iii)	With internal resistance, the effective resistance of the circuit increases / terminal p.d. decreases.
	For the same change in temperature (same change in thermistor's resistance), there is a smaller change in the voltmeter reading.

Qn	Suggested Solutions
6(a)	The magnetic flux density of a magnetic field is the force per unit length acting on a straight, current-carrying conductor,
	carrying unit current and placed at right angles to this external magnetic field.
(b)(i)	The wire exerts a downward force on the magnet.
	By Newton's third law, the magnet exerts an upward force on the wire.
(ii)	A to B
(iii)	$F = BIl\sin\theta$ $= BIl\sin(90°)$ $= (3.7\times10^{-3})(4.6)(8.5\times10^{-2})$
	$F = 1.447\times10^{-3}$ $\approx 1.4\times10^{-3}$ N
(iv)	Assume θ is the angle of rotation from the initial position. length of wire in magnetic field $= \dfrac{l}{\cos\theta}$
	$F = BI\left(\dfrac{l}{\cos\theta}\right)\left[\sin(90° - \theta)\right]$ $F = BI\left(\dfrac{l}{\cos\theta}\right)(\cos\theta)$ $F = BIl$ The force acting on the wire is independent of the angle of rotation.

Qn	Suggested Solutions
7(a)	Binding energy per nucleon is a maximum/close to the maximum at around A = 56.
	Products of splitting a $^{56}_{26}Fe$ nucleus have a lower total binding energy which requires a net input of energy
(b)	energy released $= \text{BE of products} - \text{BE of reactants}$ $= (1.273 + 0.8405 - 1.910)(1.66 \times 10^{-27})(3.00 \times 10^{8})^2$
	$= 3.04 \times 10^{-11}$ J
(c)	$\lambda = \frac{\ln 2}{28.8 \text{ yrs}}$ $N = N_0 e^{-\lambda t}$ $\frac{N}{N_0} = e^{-\frac{\ln 2}{28.8}(144)}$ $= \frac{1}{32}$ $R = \frac{N_0 - N}{N}$ $= \frac{N_0}{N} - 1$ $= 32 - 1$ $= 31$ OR no. of half-lives $= \frac{144}{28.8}$ = 5.00 $N = \frac{N_0}{2^5}$ $= \frac{1}{32} N_0$ $R = \frac{N_0 - N}{N}$ $= \frac{N_0}{N} - 1$ $= 32 - 1$ $= 31$
(d)(i)	$N_0 = \frac{0.13}{90 \times 1.66 \times 10^{-27}}$ $= 8.7 \times 10^{23}$
(ii)	$A_0 = \lambda N_0$ $= \left(\frac{\ln 2}{28.8 \times 365 \times 24 \times 60 \times 60}\right)(8.70 \times 10^{23})$ $= 6.64 \times 10^{14}$ $\approx 6.6 \times 10^{14}$ Bq
(iii)	$P = A \times \text{energy released per decay}$ $= (6.64 \times 10^{14})(0.546 \times 10^{6} \times 1.60 \times 10^{-19})$
	$P = 58$ W

Qn	Suggested Solutions
8(a)	unit of Z = $(\text{unit of } \rho)^a (\text{unit of } \kappa)^b$ $\text{kg m}^{-2}\ \text{s}^{-1} = (\text{kg m}^{-3})^a (\text{m kg}^{-1}\ \text{s}^2)^b$ $= \text{kg}^{a-b}\ \text{m}^{-3a+b}\ \text{s}^{2b}$
	Comparing the powers, $2b = -1$ $b = -\frac{1}{2}$ $a - b = 1$ $a = 1 - \frac{1}{2}$ $= \frac{1}{2}$
(b)(i)	$\frac{I_r}{I_i} = \frac{(Z_{mus} - Z_{bone})^2}{(Z_{mus} + Z_{bone})^2}$ $= \frac{(1.71 - 7.63)^2}{(1.71 + 7.63)^2}$
	$\frac{I_r}{I_i} = 0.402$
(ii)	A significant fraction of the ultrasound beam will not be able to reach the heart as 40% of it gets reflected by the ribs.
(iii)	Liver and kidney
	(It is difficult to detect a boundary if the ultrasound is not reflected from the boundary. $\frac{I_r}{I_i}$ is a minimum when the impedance of the two tissues is as small as possible. i.e. when $Z_1 - Z_2$ is smallest since denominator are similar order of magnitude.)
(c)(i)	$\frac{I}{I_0} = e^{-\mu f x}$ $\frac{1}{2} = e^{-0.23(5.0)x}$
	$x = 0.60$ cm
(ii)	Based on the formula, $I = I_0 e^{-\mu f x}$ For I to be constant, f must decrease for x to increase OR To ensure that the ultrasound beam has a minimum intensity for detection when it enters deeper into the body, it must be attenuated less / its intensity should decrease at a slower rate.
	Low frequency ultrasound waves should be used.

(d)(i)	$\dfrac{I_t}{I_i} = \dfrac{4Z_{PZT}Z_{skin}}{\left(Z_{PZT}+Z_{skin}\right)^2}$ $= \dfrac{4\left(30\times10^5\right)\left(1.7\times10^5\right)}{\left(30\times10^5+1.7\times10^5\right)^2}$
	$\dfrac{I_t}{I_i}\times100\% = 0.203\times100\%$ $= 20.3\%$ $\approx 20\%$ (Shown)
(ii)	$Z_{matching\ layer} = \sqrt{Z_{PZT}Z_{skin}}$ $= \sqrt{\left(30\times10^5\right)\left(1.7\times10^5\right)}$ $= 7.14\times10^5\ \text{g cm}^{-2}\ \text{s}^{-1}$
	$\dfrac{I_t}{I_i} = \dfrac{4Z_{PZT}Z_{matching\ layer}}{\left(Z_{PZT}+Z_{matching\ layer}\right)^2}$ $= \dfrac{4\left(30\times10^5\right)\left(7.14\times10^5\right)}{\left(30\times10^5+7.14\times10^5\right)^2}$ $= 0.621$
	$\dfrac{I_t}{I_i} = \dfrac{4Z_{matching\ layer}Z_{skin}}{\left(Z_{matching\ layer}+Z_{skin}\right)^2}$ $= \dfrac{4\left(7.14\times10^5\right)\left(1.7\times10^5\right)}{\left(7.14\times10^5+1.7\times10^5\right)^2}$ $= 0.621$
	(Since $P = IA$, efficiency is proportional to the ratio of intensities.) efficiency $= 0.621^2\times100\%$ $= 38.6\%$ $\approx 39\%$
(iii)	thickness $= \dfrac{1}{4}\lambda$ $= \dfrac{1}{4}\left(\dfrac{v}{f}\right)$ $= \dfrac{1}{4}\left(\dfrac{2500}{5.0\times10^6}\right)$ $= 1.25\times10^{-4}\ \text{m}$

(e)	
(f)	Ionising radiation interacts with water in the cells and break the bonds that hold the water molecule together, producing H and OH free radicals.
	Free radicals combine to form toxic substances like H_2O_2 which can destroy the cell.