Section A

1	(a)	(i)	Define *acceleration* Acceleration is the rate of change of velocity with respect to time	[1]
		(ii)	Use your definition in (a)(i) and the definition of average velocity, to show that for constant acceleration $v^2 = u^2 + 2as$ where v is the final velocity, u is the initial velocity, a the acceleration and t the time interval For constant acceleration $a = \frac{v-u}{t}$ The displacement is given by $s = \left(\frac{v+u}{2}\right)t$ (average velocity × time) Rewriting, we get $\frac{1}{t} = \left(\frac{v+u}{2}\right)\left(\frac{1}{s}\right)$ and $a = (v-u)\left(\frac{v+u}{2}\right)\left(\frac{1}{s}\right)$ $2as = (v-u)(v+u)$ Hence $v^2 = u^2 + 2as$	[2]
	(b)	(i)	State the time at which the ball reaches its maximum height Time = 1.15 s	[1]
	(b)	(ii)	Determine the acceleration of the ball 0.5 s after leaving the thrower's hand Determine the gradient of graph at t = 0.5 s Acceleration = -17 m s^{-2} m s^{-2}	[2]

	(b)	(iii)	Based on your answer in (b), determine the drag force on the ball 0.5 s after leaving the thrower's hand Net force $F = W + F_{Drag} = ma$ $F_{Drag} = ma - mg = (0.320)(17.0) - (0.320)(9.81)$ [1] (Working) $= 2.30\ N$ [1] (Correct answer) Drag force = ______ N	[2]
	(b)	(iv)	Explain why the time taken to reach maximum height is less than the time taken on the way down to the thrower's hand. Without drag force, the speed of the ball on returning to the thrower's hand is the same as the initial speed when the ball is thrown upwards. With drag force, energy is loss to the environment. Hence the speed on return is less than the speed of throw. Therefore the average speed on the way up is larger than the average speed on the way down. [1] The distance travelled on the way up and down is the same. For the same distance travelled, the time taken is inversely proportional to the average speed. Therefore the time taken on the way up must be smaller because its average speed is larger. [1]	[2]

2	a)	(i)	loss in GPE = m g h = m g r sin θ = 0.200 (9.81) 0.850 sin 30.0° [1] = 0.834 J [1]	[2]
		(ii)	As the ball falls, it loses gravitational potential energy. To maintain constant angular velocity and to prevent the kinetic energy from increasing, the work done by the electric motor must be negative [1] to remove the energy from the system.	[1]
		(iii)	Work done = - loss in GPE= - 0.834 J [1]	[1]
	b)	(i)	mark with the letter S on the dotted circle in Fig 2.1 the position of the ball. Sketch the subsequent path taken by the ball after the glue snaps.	[2]

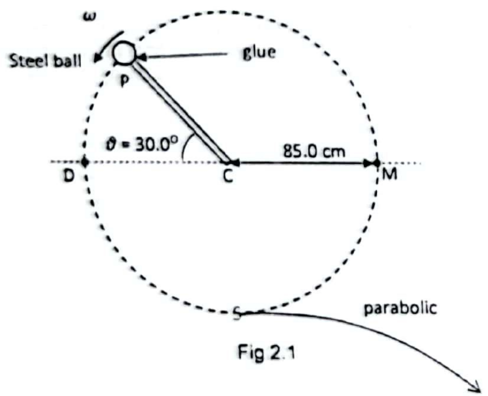


Fig 2.1

			[1] S at the bottom [1] path is tangent to the circle at the start, and curves parabolically downwards.	
		(ii)	By Newton's 2nd law, F_{net} on the ball = max glue tension - weight = ma_c $8.50 - 0.200(9.81) = 0.200(0.850)\omega^2$ [1] $\omega = 6.20$ rad s^{-1} [1]	[2]

	c)	The minimum angular speed is determined by the condition that the ball stays in contact with E at the top, where the net force is the minimum and is only provided by the weight of the ball $mg = mr\omega^2$ $9.81 = 0.85\omega^2$ [1] $\omega = 3.40$ rad s-1 [1]	[2]

3	(a)	The table below shows the pressure, volume and temperature of the ideal gas inside the metal cylinder for states A, B and C.

(i) Explain why the pressure for states A and D are the same. [1]

The pressure in the gas is given by the sum of the atmospheric pressure and the pressure due to the combined weight of the piston, connecting rod and platform. Since these components are the same for both states A and D, the pressure for State D is therefore the same as that for State A.

(ii) Complete the table by filling in the volume for state D. [2]

State	Ideal Gas		
	Pressure (kPa)	Volume (m^3)	Temperature (K)
A	102	1.000	292
B	103	0.990	292
C	103	1.197	353
D	102	1.209	353

Table 3.1

(b)

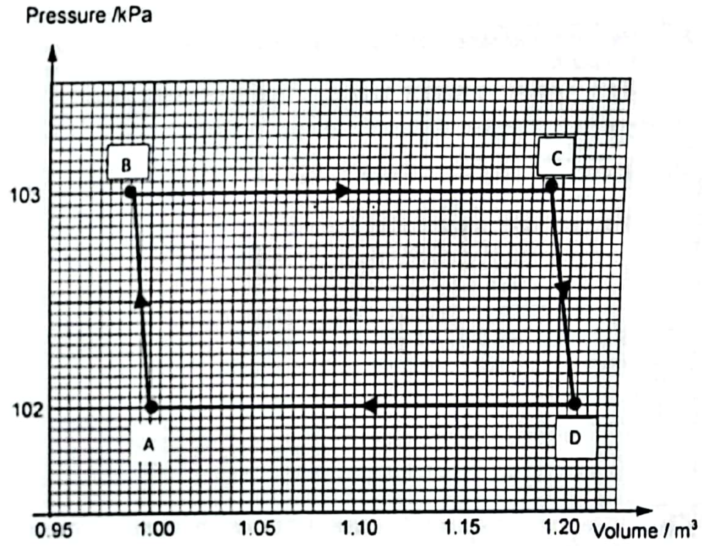


Fig. 3.3

(i) Mark and label state D on Fig. 3.3 and draw the process lines joining state C to state D to state A.

State D plotted correctly to accuracy of half the smallest square. [1]

(ii) Hence, using Fig. 3.3, estimate the work done by the ideal gas in one cycle.

Workdone is area enclosed by the graph

$W = (103000 - 102000)(1.209 - 1.000)$ [1] (Working)

$= 209\ J$ [1] (Correct answer)

Recognise that the enclosed area is approximately a parallelogram. Alternatively, area can also be obtained by counting of squares.

Work Done = 209 J [2]

(c) By considering the kinetic energy of the ideal gas in the metal cylinder, determine the amount of thermal energy, Q absorbed by the gas from the heat reservoir as it goes from state B to C.

For ideal gas, the internal energy equals its kinetic energy.

Internal energy at B,

Since $PV = nRT$, the internal energy is $U = \frac{3}{2}nRT = \frac{3}{2}PV$ [1]

The change in internal energy from B to C,

$\Delta U = \frac{3}{2}\left[(103\times10^3)(1.197) - (103\times10^3)(0.990)\right] = 31982\ J$ [1] (find change in U)

Based on the First Law of Thermodynamics

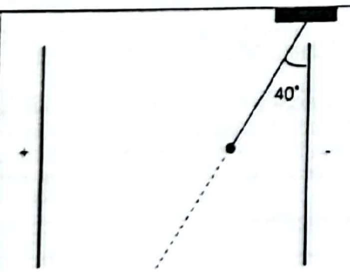
$Q = \Delta U - W = 31982 - \left[-(103\times10^3)(1.197 - 0.990)\right]$ [1] (1st Law of Thermodynamics)

$= 53303\ J$ [1] (correct answer) [4]

(f) Determine the efficiency of the heat engine. [1]

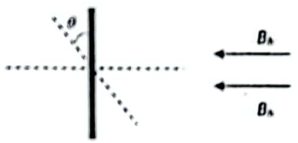
$\text{Efficiency} = \frac{\text{Output energy}}{\text{Input energy}} \times 100\%$

$= \frac{209}{32190} \times 100\% = 0.65\%$

4	(a)		Electric field strength at a point is the electric force per unit positive charge on a stationary positive small test charge placed at that point.	[1]
	(b)	(i)	Net force in the vertical direction = 0 $T\cos 40^\circ = mg$ $T = \dfrac{(0.250)(9.81)}{\cos 40^\circ}$ $T = 3.2$ N	[1]
		(ii)	1. Net force in the horizontal direction = 0 $T\sin 40^\circ = qE$ $E = \dfrac{(3.2)\sin 40^\circ}{12 \times 10^{-3}}$ $E = 170$ V m^{-1}	[1] [1]
			2. $E = \Delta V/\Delta x$ $\Delta V = E\Delta x \quad = 171 \times 0.70 \sin 40^\circ$ $= 77$ V	[1] [1]
		(iii)		[1]

		(iv)	Gain in kinetic energy = loss in gravitational PE + loss in electric PE $= mg\Delta h + qE\Delta x$ $= (0.250)(9.81)(0.70) + (0.012)(171)(0.70\tan 40^\circ)$ $= 2.9$ J	[1] [1] [1]

5	(a)		very high/infinite resistance for negative voltages up to about 0.4 V resistance decreases from 0.4 V	B1 B1
	(b)		initial straight line from (0,0) into curve with decreasing gradient but not to horizontal repeated in negative quadrant	M1 A1
	(c)	(i)	$R = 12^2 / 36 = 4.0\ \Omega$ or $I = P / V = 36 / 12 = 3.0$ A and $R = 12 / 3.0 = 4.0\ \Omega$	A1
		(ii)	$R = V / I = (12 - 0.5 \times 2.8) / 2.8$ or $E = 12 = 2.8 \times (R + r)$ $= 3.8\ (3.79)\ \Omega$ or $R = 3.8\ \Omega$	C1 A1
		(iii)	Power dissipated across filament lamp = $(2.8)^2\,(3.79) = 29.7$ W Power supplied by cell = $(2.8)(12) = 33.6$ W Percentage of power supplied by cell dissipated across the filament lamp = (29.7 / 33.6) x 100% [1] = 88.4 % [1]	[2]

6	a)		Faraday's Law of Electromagnetic Induction states that the magnitude of the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage or the rate of cutting of magnetic flux	B2
	b)	(i)	When the coil rotates, the area of the coil that is perpendicular to the horizontal component of the earth's magnetic field (B_h) changes. Thus there is a changing magnetic flux linkage in the coil. B1 By Faraday's law of EMI, an e.m.f. of magnitude directly proportional to the rate of change of magnetic flux linkage will be induced in the coil. B1 OR As the coil rotates at a constant speed, it cuts the magnetic flux due to the earth's magnetic field. B1 By Faraday's law of EMI, an e.m.f. of magnitude directly proportional to the rate of change of magnetic flux will be induced in the coil. B1	
		(ii)	 *Top view of coil* Magnitude of e.m.f. $\varepsilon = d\Phi/dt = d(nB_hA\sin\theta)/dt = d(nB_hA\sin\omega t)/dt = \omega nB_hA\cos\omega t$ Since Φ is sinusoidal, ε is also sinusoidal M1 A1	
		(iii)	$\omega = v/r = 200 \times 10^3/(3600)(0.250) = 222.2$ rad s^{-1}	A1
		(iv)	$\varepsilon_{max} = n\omega AB_h$	B1
		(v)	$n = \varepsilon_{max}/\omega AB_h = 15 \times 10^{-3}/222.2 \times 10^{-2} \times 1.5 \times 10^{-5} = 450$ turns	A1
		(vi)	The rod which holds the cups is rotating at right angles to the vertical component of the Earth's magnetic field, and therefore is acting as a crude form of spinning Faraday's disk. The e.m.f. is established between the centre and either ends of the rod, hence there will be no potential difference across the two ends of each metal rod during rotation at maximum speed.	

Section B

Q	Part	Sub	Answer	Mark
7	(a)	(i)	$f = 1/T = 1/0.50 = 2.0$ Hz	A1
		(ii)	$a = -\omega^2 x \rightarrow \omega^2 = \left(\frac{\rho A g}{m}\right)$	M1
			$\rightarrow 4\pi^2 f^2 = \left(\frac{\rho A g}{m}\right) \rightarrow \rho = \frac{4\pi^2 f^2 m}{Ag}$	M1
			$\rho = \frac{4\pi^2 (2.0)^2 0.032}{4.2\times10^{-4}(9.81)} = 1226 \text{ kg m}^{-3}$	A1
		(iii)	The energy of the oscillations is given by $\frac{1}{2}m\omega^2 x^2$, where x is the displacement from the equilibrium point.	M1
			$E_{t=0} = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2}0.032(4\pi^2 2.0^2)(-1.5)^2 = 5.68\times10^{-4}$ J	M1
			$E_{t=1.50\,s} = \frac{1}{2}m\omega^2 x_{1.50}^2 = \frac{1}{2}0.032(4\pi^2 2.0^2)(-0.65)^2 = 1.07\times10^{-4}$ J	
			% loss $= \frac{5.68\times10^{-4}\text{ J} - 1.07\times10^{-4}\text{ J}}{5.68\times10^{-4}\text{ J}} = 81\%$ loss	A1
		(iv)	As the liquid is more viscous, greater damping forces will act on the tube. More negative work done by the tube against these forces per oscillation.	M1
			Hence, the tube oscillates with much less energy in this liquid. Energy is directly proportional to the square of the amplitude. Therefore, the tube oscillates at smaller amplitudes.	M1 A0
	(b)	(i)	The amplitude of vibration is the same at all points in a travelling (progressive) wave but it varies with position in a stationary wave, from zero at nodes to maximum at antinodes.	M1 M1
			The energy is being transmitted in a travelling wave however it is stored/not transmitted in a stationary wave.	M1
		(ii)	Shape X: Sine wave with less amplitude Shape Y: Horizontal line Shape Z: Negative sine wave with less amplitude	M1 M1 M1
	(c)	(i)	5 fringe separations = 10.4 mm $\Delta y = \frac{\lambda L}{d}$	M1

Q	Part	Sub	Answer	Mark
			$\frac{10.4\times10^{-3}}{5} = \frac{633\times10^{-9}(2.95)}{d}$ $d = 8.98\times10^{-4}$ m = 0.898 mm	M1
		(ii)	Any of 3 below: • Greater angle for bright spots (principal maxima) • Less number of bright spots • Greater intensity at bright spots • Greater distance between subsequent bright spots	M1 M1 M1
8	(a)	(i)	${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e} + \gamma$ [B1] for e. [B1] for the other 2.	[2]
		(ii)	Number of nuclei in 1 g of C0-60 $= \frac{1}{60}\times6.02\times10^{23}$ [M1] $= 1.003\times10^{22}$	[1]
		(iii)	$A = \lambda N$ $= \frac{\ln 2}{5.272\times265\times24\times60\times60}1.003\times10^{22}$ [M1] $= 4.182\times10^{13}$ Bq radiation power $= (4.182\times10^{13})\times2.8$ $= 1.171\times10^{20}$ eV = 18.7 W [A1]	[2]
	(b)	(i)	A packet of electromagnetic radiation energy of [1] energy > 100 keV OR wavelength < 10 pm. [1]	[2]
		(ii)	Method 1 $E = \frac{hc}{\lambda}$ $(1.3\times10^6)(1.60\times10^{-19}) = \frac{(6.63\times10^{-34})(3.0\times10^8)}{\lambda}$ [M1] $\lambda = 9.5625\times10^{-13}$ m	[2]

$$p = \frac{h}{\lambda} = \frac{(6.63 \times 10^{-34})}{9.5625 \times 10^{-13}} = 6.93 \times 10^{-22} \text{ kg m s}^{-1}$$ [A1]

Method 2

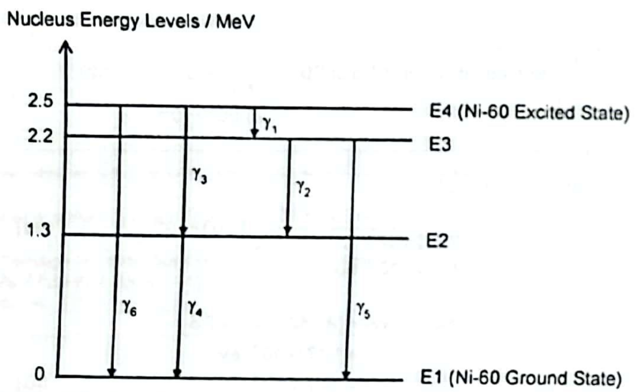
From $\lambda = \frac{h}{p}$ and $E = \frac{hc}{\lambda}$, we obtain $E = pc$

$$p = \frac{E}{c} = \frac{(1.3 \times 10^{6})(1.60 \times 10^{-19})}{3.00 \times 10^{8}}$$

$$= 6.93 \times 10^{-22} \text{ kg m s}^{-1}$$

(iii) When the nucleus de-excites from a higher to lower energy level, a gamma photon of energy equal to the energy transition is emitted. [B1]
Since the energy levels of the nucleus is discrete, the emission spectrum is a line **spectrum** [B1] [2]

(iv) 1.



[2]

2.

$\Delta E = \Delta m.c^2$

$$(2.5 \times 10^{-6})(1.60 \times 10^{-19}) = \Delta m.(3.00 \times 10^{8})^2$$ [M1]

$$\Delta m = 4.444 \times 10^{-30} \text{ kg}$$

$$= 0.0002677 \text{ u}$$

At excited state

$$m = 59.93079 + 0.0002677 = 59.93347u$$ [A1]

By the mass-energy equivalence principle, the mass of the excited nucleus has more energy and therefore larger mass than the nucleus in its ground state. [B1] [3]

(c) (i) Energy of beta-particle = 2.8 – 2.5 = 0.3 MeV [M1]

$$\frac{hc}{\lambda_{min}} = E_{\beta}$$

$$\frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{\lambda_{min}} = (0.3 \times 10^{-6})(1.6 \times 10^{-19})$$

$$\lambda_{min} = 4.14 \times 10^{-12} \text{ m}$$ [A1] [2]

(ii) Beta-particles knock the innermost shell electrons out of the lead atoms, creating vacancies in the innermost shell. [B1]
When electrons from higher shells cascade down to fill the vacancy, X-ray photons with energy corresponding to the energy transitions are emitted. [B1] [2]