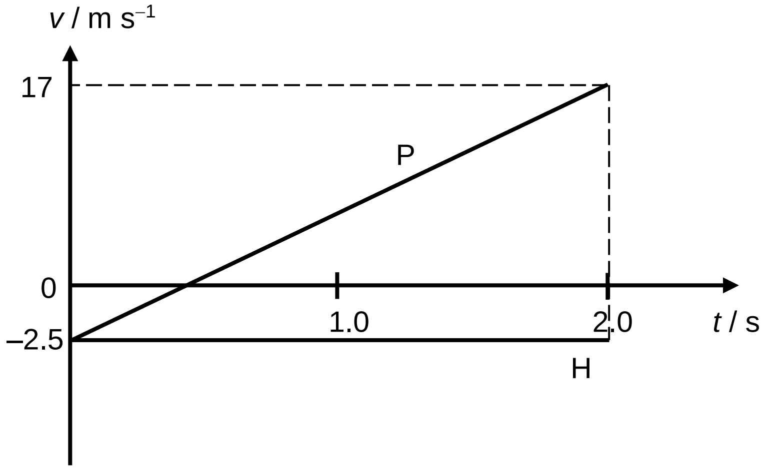
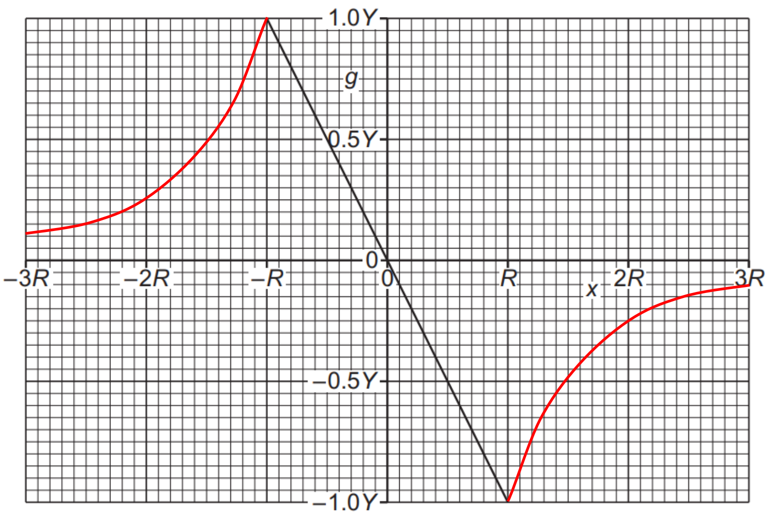
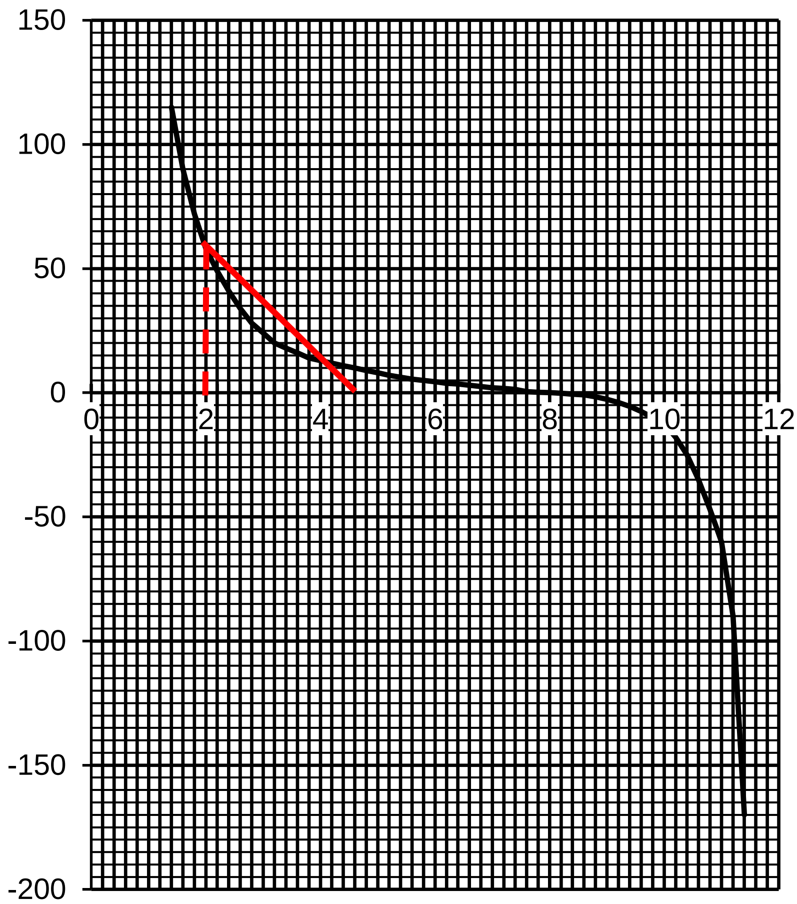
Answers to 2024 JC2 H2 Preliminary Examinations Paper 3

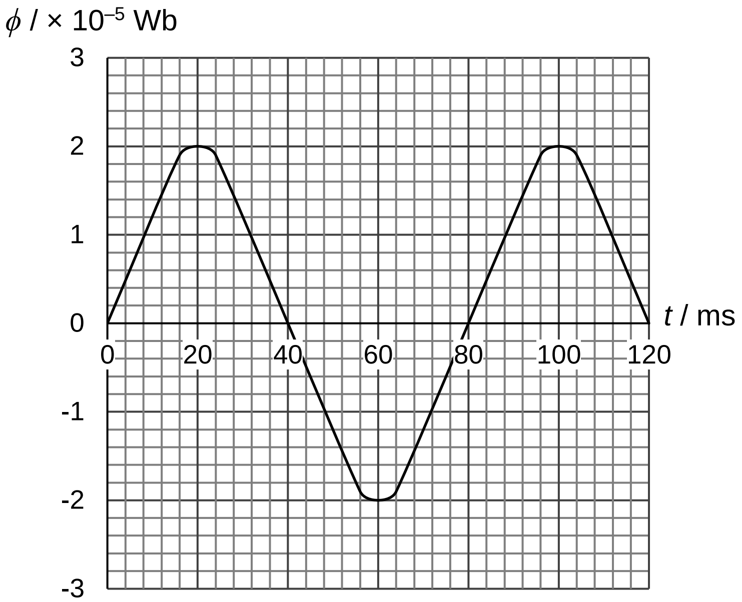
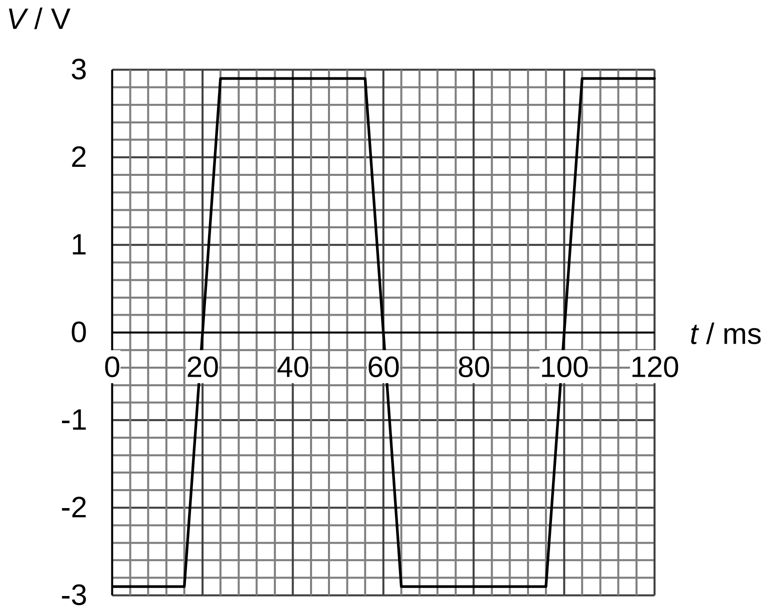
Suggested Solutions:

No.	Solution	Remarks
1(a)	$v = u + at = -2.5 + (9.81)(2.0)$ $= 17.1$ Speed is 17 m s^{-1}	[1] substitution [1] answer
1(b)		[1] helicopter: horizontal straight line (-ve value) [1] parcel: diagonal straight line (+ve gradient) (reverse sign accepted) [-1] if not labelled
1(c)	Distance between helicopter and parcel = area of right-angled triangle = $\frac{1}{2}(2.0)(17.1+2.5) = 19.6$ m OR From point of release, For helicopter, upwards $s = ut = (2.5)(2.0) = 5.0$ m For parcel, downward $s = ut + \frac{1}{2}at^2$ $= (-2.5)(2.0) + \frac{1}{2}(9.81)(2.0)^2$ $= 14.6$ m Hence their separation = 5.0 + 14.6 = 19.6 m	[1] working [1] answer
2(a)	The change in height is negligible compared with radius of the planet. Thus, the field strength $g = \frac{GM}{R^2}$ remains relatively constant for any small change in R. The gravitational field lines are effectively parallel.	[1]
2(b)(i)	$Y = \frac{GM}{R^2}$ where G is the gravitational constant	[1]

2(b)(ii)		[1] for correct shape of curve from $-3R$ to $-R$; ending at $(-R,\ 1.0Y)$ [1] for correct shape of curve from R to $3R$; starting at $(R,\ -1.0Y)$ [1] for curves passing through $(-3R,\ 0.11Y)$; $(-2R,\ 0.25Y)$; $(2R,\ -0.25Y)$; $(3R,\ -0.11Y)$ (don't need to mark for ±3R)
2(b)(iii)	Initial total energy = Final total energy $\frac{1}{2}mv^2 - \frac{GMm}{R} = \frac{1}{2}\left(\frac{1}{2}mv^2\right) - \frac{GMm}{x}$ $\frac{1}{4}v^2 = GM\left(\frac{1}{R} - \frac{1}{x}\right)$ $\frac{1}{4}\left(4.7\times10^3\right)^2 = \left(6.67\times10^{-11}\right)\left(6.4\times10^{23}\right)\left(\frac{1}{3.4\times10^6} - \frac{1}{x}\right)$ $x = 6.070\times10^6$ m Therefore distance travelled $= x - R$ $= 6.070\times10^6 - 3.4\times10^6$ $= 2.670\times10^6$ m $= 2.7\times10^6$ m	[1] for correct equation for conservation of energy [1] for correct substitution [1] for correct answer
3(a)	The electric field strength in both sphere A (between x = 0 and x = 1.4 cm) and sphere B is zero (between x = 11.4 and x = 12.0 cm).	[1]
3(b)(i)	The resultant field strength is zero at a point between the spheres and this shows that electric fields are in opposite directions in the region between the two spheres. This shows that the polarity of the two charges are the same. Hence, since sphere A is positively charged, sphere B must also be positively charged.	[1] expl [1] state

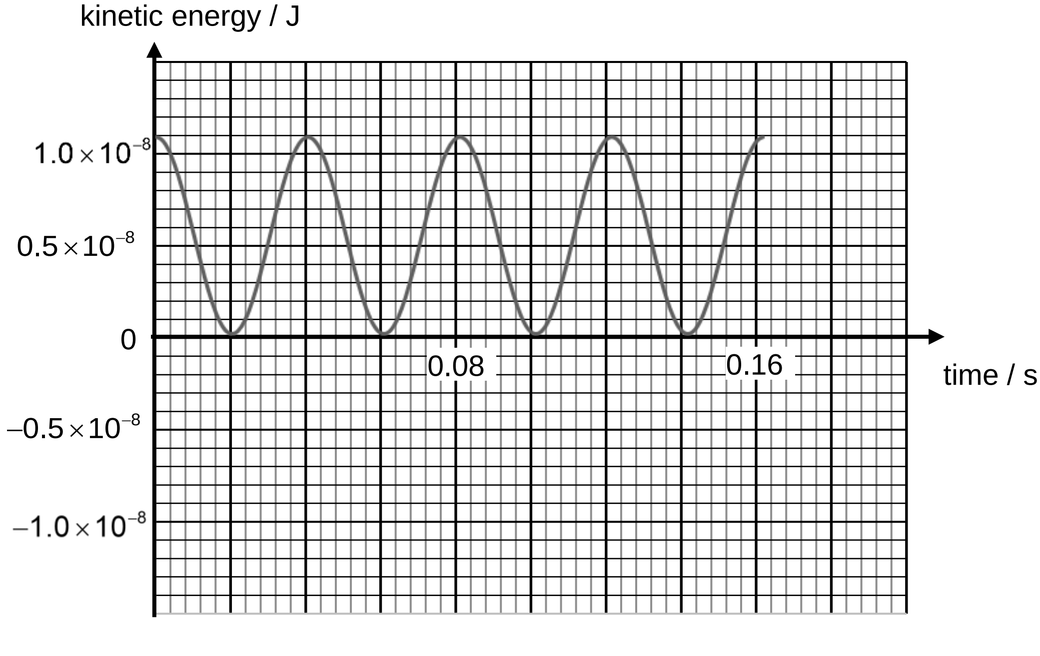
3(b)(ii)	At x = 0.08 m, the electric field strength due to sphere A cancels out the electric field strength due to sphere B. $E_A = E_B$ $\frac{Q_A}{4\pi\varepsilon_o (0.08)^2} = \frac{Q_B}{4\pi\varepsilon_o (0.04)^2}$ $\frac{Q_A}{Q_B} = \left(\frac{0.08}{0.04}\right)^2 = 4$	[1] sub [1] ans
3(c)(i)	The electric field strength is <u>negative of the electric potential gradient</u>, i.e. $E = -\frac{dV}{dx}$	[1] don't accept $E = -\frac{dV}{dx}$
3(c)(ii)	 From $E = -\frac{dV}{dx} \Rightarrow \Delta V = -\int_{x=2cm}^{x=8cm} E\ dx$ Hence, change in potential, ΔV = negative of area under $E-x$ graph (from x = 2.0 cm to x = 8.0 cm) By approximation, area of triangle ≈ area under $E-x$ graph (from x = 2.0 cm to x = 8.0 cm)	[1] ΔV = area under $E-x$ graph [1] value of ΔV

	$\Delta V = -\frac{1}{2}\left(2.6\times10^{-2}\right)\left(60\times10^{6}\right) = -7.8\times10^{5}$ V Work done $= \left(-7.8\times10^{5}\right)\left(-2.0\times10^{-6}\right) = 1.6$ J	[1] ans accept 1.4 J to 1.8 J
4(a)	The magnetic flux linkage is the product of the number of turns of the coil of wire and the magnetic flux through (each turn of) the coil of wire. The magnetic flux through an area is defined as the product of that area and the component of the magnetic flux density normal to the plane of that area.	[1] [1]
4(b)(i)	$\phi_{max} = B_{max}A$ $= \left(\mu n I_{max}\right)A$ $= (1000\times4\pi\times10^{-7})\left(\frac{1800}{0.12}\right)(1.05\times10^{-3})\left(\frac{\pi\times0.036^{2}}{4}\right)$ $= 2.014\times10^{-5}$ Wb $= 2.0\times10^{-5}$ Wb	[1] substitution for B_{max} only [1] unrounded value for max flux
4(b)(ii)	By Faraday's law of EMI, $E_{induced} = -\frac{d\Phi}{dt}$ $= -\frac{d(N_Q BA)}{dt}$ $= -N_Q A\frac{d(1000\mu_0 nI)}{dt}$ $= -1000 N_Q A\mu_0 n\frac{dI}{dt}$ $\frac{dI}{dt} = \frac{[1.0-(-1.0)]\times10^{-3}}{(24-56)\times10^{-3}}$ $E_{induced} = -(1000)(2400)\left(\frac{\pi(0.036)^{2}}{4}\right)(4\pi\times10^{-7})\left(\frac{1800}{0.12}\right)\frac{dI}{dt}$ $= 2.88$ V	[1] for correct substitution of μnA [1] correct gradient from Fig. 4.2 [1] for correct substitution of N_Q [1] for final answer

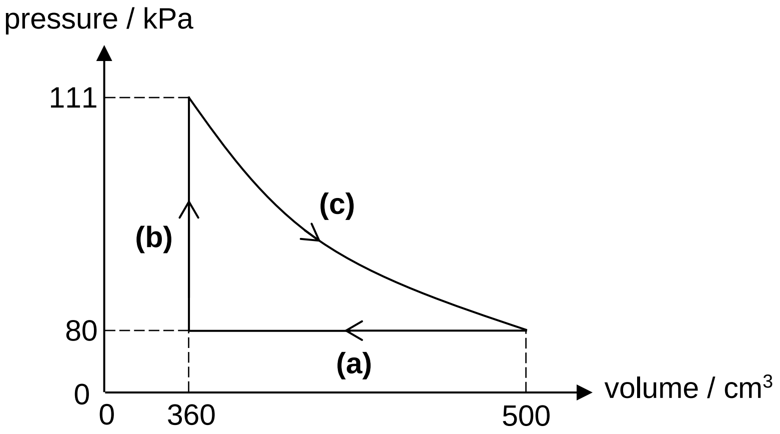
4(b)(iii)		[1] for $\phi - t$ graph [1] for $V - t$ graph [1] for correct scale on vertical axes of both graphs
5(a)	Mean power $\langle P \rangle = I_{r.m.s.}^2 R$ $= \left(\frac{2.7}{\sqrt{2}}\right)^2 (50)$ $= 182$ W $= 180$ W	[1] sub [1] ans
5(b)	r.m.s voltage across secondary coil $V_S = I_{r.m.s.} R$ $= \left(\frac{2.7}{\sqrt{2}}\right)(50)$ $= 95.5$ V	[1] value

	Turns ratio, $\frac{N_P}{N_S}=\frac{V_P}{V_S}$ $\frac{25}{N_S}=\frac{20}{95.46}$ $N_S=\frac{(25)(95.5)}{20}$ $=119=120$	[1] ans
5(c)	For the current in the secondary coil, Period $T=\frac{50\times10^{-3}}{3}=1.67\times10^{-2}$ Frequency $f=\frac{1}{1.67\times10^{-2}}$ $=60$ Hz Hence, the frequency of the alternating voltage supply is 60 Hz since it is the same as the frequency of the current through the secondary coil.	[1] correct T [1] ans and statement
5(d)	The values of the root-mean-square current and voltage of the alternating voltage supply are independent of its frequency. The mean power due to the alternating voltage supply is constant. Since the transformer is ideal, the mean power dissipated across R remains unchanged.	[1] [1]
6(a)	Threshold frequency refers to the minimum frequency of the illuminating electromagnetic radiation that will cause a photoelectron to be ejected for a particular metal.	[1]
6(b)(i)	Energy of a photon, $E=\frac{hc}{\lambda}=\frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{450\times10^{-9}}=4.42\times10^{-19}$ J	[1] sub [1] ans
6(b)(ii)	Power incident on metal, $P=(2.7\times10^{3})(3.0\times10^{-4})=0.81$ W $P=\left(\frac{N}{t}\right)E$ $\Rightarrow\frac{N}{t}=\frac{P}{E}=\frac{0.81}{4.42\times10^{-19}}=1.83\times10^{18}\ \text{s}^{-1}$	[1] value [1] ans
6(b)(iii)	Max. K.E. = $eV_s=(1.6\times10^{-19})(1.6)=2.56\times10^{-19}$ J Applying Einstein Photoelectric equation, Work function, $\phi=hf-\text{max. K.E.}=4.42\times10^{-19}-2.56\times10^{-19}=1.86\times10^{-19}$ J	[1] value [1] value

	Threshold wavelength, $\lambda = \frac{hc}{\phi} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{1.86\times10^{-19}} = 1.07\times10^{-6}$ m	[1] ans
6(c)(i)	From the graph, λ_{min} is the same for both spectra. $eV = \frac{hc}{\lambda_{min}} \Rightarrow V = \frac{hc}{e\lambda_{min}}$	[1]
6(c)(ii)	From the graph, $\lambda_{min} = 16\times10^{-12}$ m $V = \frac{hc}{e\lambda_{min}} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{1.60\times10^{-19}\times16\times10^{-12}} = 7.8\times10^{4}$ V	[1] sub [1] ans
7(a)(i)	The half-life of a radioactive nuclide is the time taken for the activity of a sample to reduce to half its initial value.	[1] answer
7(a)(ii)	The decay constant is the fraction of the total number of nuclei in a sample that decay per unit time.	[1] answer
7(b)(i)	$E = \Delta m\, c^2 = 0.7060$ MeV $= (0.7060)(1.6\times10^{-13})$ $= 1.1296\times10^{-13}$ J → $\Delta m = \frac{E}{c^2} = \frac{1.1296\times10^{-13}}{(3\times10^{8})^2} = 1.2551\times10^{-30}$ kg $= \frac{1.2551\times10^{-30}}{1.66\times10^{-27}} = 7.5609\times10^{-4}\ u$ $M_N + M_n - (M_C + M_X) = 7.5609\times10^{-4}\ u$ → $M_X = 1.00858\ u - 7.5609\times10^{-4}\ u = 1.007825\ u = 1.01u$	[1] Δm in kg [1] convert kg to u [1] answer
7(b)(ii)1.	Number produced $= \frac{7500}{14}(6.02\times10^{23}) = 3.2\times10^{26}$	[1] answer
7(b)(ii)2.	The probability of decay of the nucleus in a time of 1.0 year is the decay constant of the nucleus in that period of time. Decay constant, $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{5.7\times10^{3}} = 1.22\times10^{-4}$ year^{-1}	[1] answer
8(a)	Simple harmonic motion occurs when the acceleration of the object is directly proportional to its displacement from its equilibrium position and the acceleration is towards the equilibrium position/opposite to its displacement.	[1] [1]
8(b)(i)	$\omega = 2\pi f = 2\pi(33) = 66\pi$ $x = 2.1\times10^{-3}\sin[(66\pi)t]$	[1] correct amplitude and ω [1] any correct equation

8(b)(ii)	A distance of 0.8 mm to the right means the brush head is 1.3 mm from its equilibrium point. $x = 2.1\times10^{-3}\sin\left[(66\pi)t\right]$ $1.3\times10^{-3} = 2.1\times10^{-3}\sin\left[(66\pi)t\right]$ $t = 3.2\times10^{-3}$ s $v = (2.1\times10^{-3})(66\pi)\cos\left[(66\pi)t\right]$ $= (2.1\times10^{-3})(66\pi)\cos\left[(66\pi)(3.2\times10^{-3})\right]$ $= 0.34$ m s^{-1}	[1] correct x [1] correct substitution [1] correct ans
8(c)	$v = 9.2\times10^{-2}\cos 77t$ $v_o = \omega x_o = 9.2\times10^{-2}$ $(77)x_o = 9.2\times10^{-2}$ $x_o = 1.2\times10^{-3}$ m	[1] correct v_o substitution [1] correct answer
8(d)(i)	$v = 9.2\times10^{-2}\cos 77t$ $\max K.E. = \frac{1}{2}mv_o^2 = \frac{1}{2}(2.5\times10^{-6})(9.2\times10^{-2})^2 = 1.1\times10^{-8}$ J	[1] correct K.E. substitution [1] correct answer
8(d)(ii)	 [1] for correct shape over 2 periods [1] for correct calculation of period T [1] for correct labelling of both axes $\omega = \frac{2\pi}{T} = 77$ $T = 0.082$ s	

8(d)(iii)	Frequency is $f = \frac{77}{2\pi}$ Hz. The time interval is $\frac{3}{4}T = \frac{3}{4f} = \frac{3(2\pi)}{4(77)} = 0.061$ s.	[1] for $\frac{3}{4}T$ [1] ans
8(e)(i)1.	A forced oscillation is one which is driven <u>by an external force</u> such that energy is supplied to the oscillation.	[1]
8(e)(i)2.	The effect illustrated is called resonance.	[1]
8(e)(ii)	<u>same starting point</u> and <u>lower graph peak</u> maximum amplitude at same / lower frequency within original shape	[1] [1]
9(a)(i)	At constant pressure, $V \propto T$ $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ $\frac{500}{V_2} = \frac{250}{180}$ $V_2 = 360 \text{ cm}^3$ work done on gas $= -p\Delta V$ $= -(80\times10^3)(360-500)\times10^{-6}$ $= 11.2$ J	[1] for correct V_2 [1] for substitution [1] for answer
9(a)(ii)	Using *pV=nRT*, $n = \frac{pV}{RT} = \frac{(80\times10^3)(500\times10^{-6})}{(8.31)(250)} = 0.01925$ mol Change in internal energy, $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(0.01925)(8.31)(180-250) = -16.8$ J OR Change in internal energy, $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}p\Delta V$ $= \frac{3}{2}(80\times10^3)(360-500)\times10^{-6} = -16.8$ J	[1] for substitution [1] for answer
9(a)(iii)	Using first law of thermodynamics, $\Delta U = Q + W$ $Q = \Delta U - W$ $= -16.8 - 11.2$ $= -28.0$ J Hence, the amount of heat lost is 28.0 J.	[1] for answer (must be positive)

9(b)(i)	Using $pV=nRT$, $p=\frac{nRT}{V}=\frac{(0.01925)(8.31)(250)}{(360\times10^{-6})}=111\text{ kPa}$	[1] for substitution [1] for answer
9(b)(ii)	Change in internal energy, $\Delta U=\frac{3}{2}nR\Delta T=\frac{3}{2}(0.01925)(8.31)(250-180)=16.8\text{ J}$ Since there is no work done on the gas as volume is constant, $\Delta U=Q$ $Q=mc\Delta T=16.8$ $c=\frac{16.8}{(0.23\times10^{-3})(250-180)}=1043\approx1040\text{ J kg}^{-1}\text{ K}^{-1}$	[1] correct explanation and application of $\Delta U=Q$ [1] for substitution [1] for answer
9(b)(iii)	$\frac{3}{2}nRT=\frac{1}{2}m_{\text{total}}\langle c^2\rangle$ $c_{\text{r.m.s.}}=\sqrt{\frac{3nRT}{m}}=\sqrt{\frac{3(0.01925)(8.31)(250)}{(0.23\times10^{-3})}}$ $=722.2\approx720\text{ m s}^{-1}$	[1] substitution [1] answer
9(b)(iv)	The root-mean-square speed of the particles would remain the same. This is because the root-mean-square speed for each particle is only dependent on the temperature and not on the amount of gas, given that the mass of each particle is the same.	[1] [1]
9(c)		[1] for each process [-1] for missing axis labels
9(d)	Since the work done by the gas during expansion is greater than the work done on the gas during compression, there is a <u>net work done by the gas</u> in each cycle. Since there is no change in internal energy in each cycle, the <u>gas gains heat</u> in each cycle.	[1] [1]