SECTION A

A1. (a) *1*: the lines do not go through the origin;
2: the lines are not straight (lines) / gradient is not constant; ***[2]***
Award full marks if the candidate combines the two statements.

(b) the petrol is stored in cans / initial volume of petrol not taken into account;
the radius at $t = 0$ is probably the size/radius of the can;

or

difficulty in measuring *R*;
some comment as to the whereabouts of the zero point in the experiment; ***[2]***

(c) $\lg(R) = n\lg(t) + \lg(k)$;
therefore, *n* is the gradient of the line;
suitable "triangle" to find the gradient; *(at least half the length of line)*
$n = \frac{0.20}{0.50} = 0.4$; ***[4]***
Accept an answer based on two data points.

(d) (i) by reading the value of *R* at $t = 20\,\text{ms}$ for each of the five lines / *OWTTE*; ***[1]***

(ii) smooth curve with an intercept of $R = 5.0(\pm 1.0)\,\text{m}$;
and does not go outside error bars; ***[2]***

(iii) no the line is not a straight-line;
even with the error bars it cannot be made to be a straight-line / *OWTTE*; ***[2]***
*Award **[0]** if "no" and incorrect explanation or if there is no explanation.*

(e) choice of suitable data point in the range $V = 5 \rightarrow 15$
e.g. $R = 10.5$ for $10 \times 10^{-3}\,\text{m}^3$;
$E = \frac{r^5}{t^2}$;
$= \frac{10.5^5}{(20 \times 10^{-3})^2} = 320 \times 10^6$;
divide by 10 / other chosen value of *V*;
$\approx 30\,\text{MJ}$ for $1.0 \times 10^{-3}\,\text{m}^3$ ***[4]***

A2. (a) *e.m.f.*:
the power supplied per unit current / the energy supplied per unit charge;

Ohm's law:
the resistance of a conductor is constant / current proportional to potential difference if its temperature is constant; ***[2]***

(b) (i) $(2.5 \times 0.10) = 0.25\,\text{W}$; ***[1]***

(ii) $0.23 = I^2R$;
$R = \left(\frac{0.23}{0.10^2}\right) = 23\,\Omega$; ***[2]***

(iii) power dissipated in cell $= 0.02\,\text{W} = I^2r$;
$r = \frac{0.02}{0.10^2} = 2.0\,\Omega$;

or

use $E = IR + Ir$
$2.5 = 0.10 \times 23 + 0.10r$;
$r = \frac{0.20}{0.10} = 2.0\,\Omega$; ***[2]***

(c) new internal resistance $= 4.0\,\Omega$ and new e.m.f. $= 5.0\,\text{V}$;
$5.0 = 0.15R + 0.15 \times 4.0$;
to give $R = 29\,\Omega$;
therefore, a non-ohmic device as resistance has changed/increased; ***[4]***
Allow calculation of what current should be (0.19A) if R were constant. Allow calculation based on power.

A3. (a) sensible shape of continuous spectrum;
sharp characteristic spectrum (only one need be shown);
correct labelling of characteristic spectrum; ***[3]***

(b) (i) $E(eV) = \frac{hc}{e\lambda}$;
$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 6.6 \times 10^{-11}}$;
$= 1.875 \times 10^4\,\text{eV} = 19\,\text{keV}$ ***[2]***

(ii) difference in energy levels $= 19\,\text{keV}$;
therefore, energy level $= 20 - 19 = 1.0\,\text{keV}$; *(accept –1.0 keV)* ***[2]***

SECTION B

B1. (a) before and after collision there are no forces acting on the objects;
from Newton 3 when the two bodies are in contact the forces that they exert on each other are equal and opposite / *OWTTE*;
therefore, the net force on the two balls is always zero;
therefore, there is no change in momentum (of the objects) / momentum is conserved;

or

Accept an argument based on change in momentum of each individual object.
e.g.

from Newton 3 $F_{12} = -F_{21}$; *(accept statement in words)*

$F_{12} = \frac{\Delta p_1}{\Delta t}$ and $F_{21} = \frac{\Delta p_2}{\Delta t}$;

$\frac{\Delta p_1}{\Delta t} = -\frac{\Delta p_2}{\Delta t}$;

therefore, $\Delta p_1 + \Delta p_2 = 0$; ***[4]***

(b) the blades exert a force on the air and by Newton's third law the air exerts an equal and opposite force on the blades / air has change in momentum downwards giving rise to a force and from Newton 3 there will a force upwards;
if this force equals the weight of the helicopter;
the net vertical force on the helicopter will be zero / *OWTTE*; ***[3]***

(c) $\text{area} = \pi 0.7^2$;
$= 1.5\,\text{m}^2$ ***[1]***

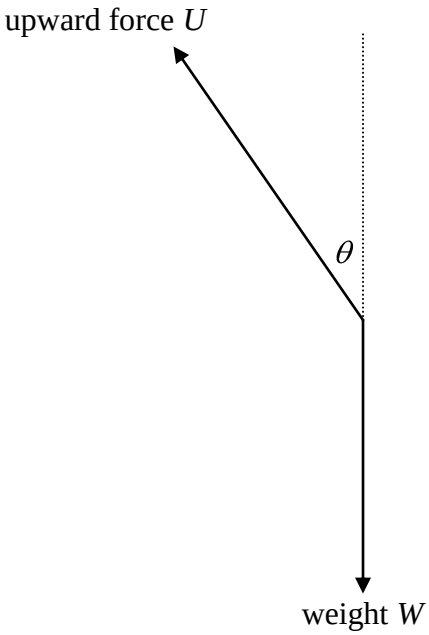
(d) (i) volume of air per second $= 1.5 \times 4.0\,(\text{m}^3\,\text{s}^{-1})$;
$\text{mass} = \text{volume} \times \text{density} = (1.2 \times 1.5 \times 4.0) = 7.2\,\text{kg}\,\text{s}^{-1}$; ***[2]***
No unit error for 7.2 kg.

(ii) momentum per second $= (7.2 \times 4.0) = 29\,\text{N}$; ***[1]***

(e) 29 N; ***[1]***

(f) recognise that the force on the blades $= Mg$;
to give $3.0\,\text{kg}$; ***[2]***

(g)



correct relative directions of forces;
upward force length greater than weight by eye;
appropriate labelling of forces;
angle θ as shown above; ***[4]***

*Award **[2 max]** if extra force(s) drawn.*

(h) the forward force is the horizontal component of *U*;
resolve vertically $U\cos\theta = W$;
horizontal component $F = U\sin\theta$;
divide to get $\frac{F}{W} = \tan\theta$;
$F = (W\tan\theta) = Mg\tan\theta = Ma$;
to give $a = g\tan\theta$ ***[5]***

*Award **[5 max]** for a correctly labelled force diagram incorporating mass with a justifying statement. Award **[1 max]** for triangle mixing accelerations and force.*

(i) work done in one cycle $= \frac{900}{300}$;
$= 3.0\,\text{J}$ ***[1]***

(j) (i) isochoric / isovolumetric; ***[1]***

(ii) $\text{B} \rightarrow \text{C}$ absorbed;
$\text{D} \rightarrow \text{A}$ ejected; ***[2]***
Accept parallel arrows.

(iii) $Q_1 - Q_2 = 3.0$;
$1 - \frac{Q_2}{Q_1} = 0.6$;
$Q_1 = 5.0\,\text{J}$ and $Q_2 = 2.0\,\text{J}$; ***[3]***

B2. Part 1 Waves

(a) no energy is transferred;
variable amplitude / variable maximum displacement of particles / *OWTTE*;
points along the wave where amplitude is always zero / reference to phase / *OWTTE*; ***[2 max]***

(b) if two or more waves overlap / *OWTTE*;
the resultant displacement at any point is found by adding the displacements produced by each individual wave / *e.g.* peak/trough meets peak/trough to give maximum/minimum / *OWTTE*; ***[2]***

(c) (i) $t = \frac{T}{4}$: straight-line; *(a line must be drawn on the diagram)*
$t = \frac{T}{2}$: negative sine; ***[2]***

(ii) the points of no displacement/nodes (at middle and ends) do not change with time;
therefore, the wave cannot be moving forward / does not progress; ***[2]***

(d) (i) maximum amplitude of oscillation;
when a periodic force is applied to it and the frequency of the force is equal to the natural frequency of vibration of the system / *OWTTE*; ***[2]***

(ii) frequency of wave $f = \frac{c}{\lambda} = \left(\frac{6.0\times10^{3}}{1.2\times10^{4}}\right) = 0.50\,\text{Hz}$;

natural frequency of oscillation of building $= \frac{1}{2.0} = 0.50\,\text{Hz}$;

the waves therefore, cause the building to resonate/vibrate violently / *OWTTE*; ***[3]***

(e) (i) the sound (heard) goes through a series of maximum and minimum intensities;
the frequency with which these occur is the beat frequency / with a regular frequency / *OWTTE*; ***[2]***

(ii) *beat frequency*:
time between two successive maxima $= 0.05\,\text{s}$;

therefore, $f = \left(\frac{1}{0.05}\right) = 20\,\text{Hz}$;

f_x:
time for one complete oscillation $= 0.01\,\text{s}$;

therefore, $f_x = \left(\frac{1}{0.01}\right) = 100\,\text{Hz}$; *(accept $100 \rightarrow 125\,Hz$)* ***[4]***

(f) 120 Hz/80 Hz; ***[1]***
Answer to be consistent with (e)(ii).

Part 2 Neutron star

(a) the force per unit mass;
exerted on a point/small mass; ***[2]***

(b) (i) energy required to move an object of mass m from the surface of the star to infinity $= m g_0 R$;
if objects KE is equal to this it will escape the gravitational influence of the star / *OWTTE*;
therefore, $\frac{1}{2} m v_e^{\ 2} = m g_0 R$;
to give $v_e = \sqrt{2 g_0 R}$ ***[3]***

(ii) $g_0 = \frac{v_e^{\ 2}}{2R}$;
$\left(\frac{3.6^2 \times 10^{14}}{2 \times 1.6 \times 10^4} \right) = 4.1 \times 10^{10}\ \text{N kg}^{-1}$; ***[2]***

(c) centripetal acceleration $= \frac{v^2}{R} = \frac{4\pi^2 R}{T^2}$;
$= \left(\frac{40 \times 1.6 \times 10^4}{4 \times 10^{-4}} \right) = 1.6 \times 10^9\ \text{m s}^{-2}$;
a comment to the effect that this is less than the gravitational field strength so that gravity will stop matter being torn away; ***[3]***
*Award **[1 max]** for calculation of linear speed ($5.0 \times 10^6\ m s^{-1}$) and a comment that this is less than the escape speed.*

B3. Part 1 Gases and liquids

(a) forces between gas molecules (except during collisions) are much smaller than between liquid molecules;
speed of gas molecules much greater than speed of liquid molecules;
motion/movement of gas molecules is less restricted than that for liquid molecules;
<u>average</u> separation of molecules much greater in a gas than in a liquid; ***[2 max]***

(b) the molecules do not have the same speed / the molecules have different speeds;
the speed of the molecules change each time they collide / the speed of individual molecules is always changing / *OWTTE*; ***[2]***
Accept use of words "kinetic energy" in place of speed.

(c) the energy/heat required to raise/change the temperature of a substance by $1\,\text{K}/^{\circ}\text{C}$; ***[1]***

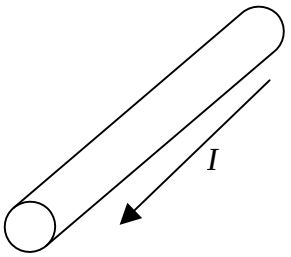
(d) (i) the water is changing phase/boiling / KE of molecules is constant, (PE is changing); ***[1]***

(ii) $\text{time} = 420\,(\text{s})$;
$\text{energy supplied} = 300 \times 420$;
$= 4.2 \times 10^3 \times 0.40 \times \Delta\theta$;
to give $\Delta\theta = 75$;
therefore, boiling temperature $\theta = 95^{\circ}\text{C}$; ***[5]***

(e) $300 \times 3.0 \times 10^3 = 0.40\,L$;
to give $L = 2.3 \times 10^6\ \text{J kg}^{-1}$; ***[2]***

Part 2 Electrical conduction and induced currents

(a) the force on the electrons produced by the electric field causes them to accelerate along the direction of the rod;
however, they will (soon) collide with a lattice ion but after collision will again be accelerated (along the rod) before making another collision / *OWTTE*;
hence the electrons gain a drift/net velocity in the direction of the wire / in the (opposite) direction to the field even though they still have random velocities / *OWTTE*; ***[3]***

(b) (i) 

; ***[1]***

(ii) Lenz's law says that the direction of the induced current is such as to oppose change;
therefore, to produce a (magnetic) force that opposes *F* the current must be in direction shown / reference to left/right hand rule / *OWTTE*; ***[2]***

(iii) the force on the electrons is given by *Bev*;
as *v* increases so does this force and therefore, so does the induced current;
therefore, net force on rod decreases / *OWTTE*; ***[3]***

(c) (i) the induced e.m.f. is equal/proportional to the rate of change/cutting of (magnetic) flux; ***[1]***

(ii) if the rod moves a distance Δx in time Δt then area swept out by rod $= l\Delta x$;
flux $= Bl\Delta x$;
rate of change of flux $= \dfrac{Bl\Delta x}{\Delta t} = Blv = \mathcal{E}$; ***[3]***

(iii) *induced current*:
$I = \dfrac{F}{Bl}$;
substitute to give $I = 3.1\text{A}$;

speed v:
$\mathcal{E} = IR = 0.47$;
$\mathcal{E} = Bvl$ substitute to give $v = 4.5(4.4)\,\text{m s}^{-1}$; ***[4]***

B4. Part 1 Radioactive decay

(a) (i) proton or neutron; ***[1]***

(ii) proton $\rightarrow$ UUD / up, up down;
neutron $\rightarrow$ UDD / up down down; ***[2]***
*Award **[1 max]** if transposed.*

(iii) both have the same number of protons but different number of neutrons;
strong force and Coulomb force between nucleons;
in Ar-36 strong force attraction and Coulomb repulsion balanced therefore nucleus stable;
in Ar-39 excess neutrons lead to an imbalance in forces hence nucleus unstable; ***[4]***
Accept answer in terms of energy i.e. excess neutrons raises the PE of the nucleus.

(b) (i) $Z = 19$;
$N = 39$;
$x \rightarrow$ anti-neutrino / $\tilde{\nu}$; ***[3]***

(ii) (in beta decay) beta energy spectra are continuous;
this implies energy is not conserved (in beta decay);
the particle x/the anti-neutrino was postulated to account for the missing energy / *OWTTE*; ***[3]***

(iii) $\Delta m = 0.00061\,\text{u}$;
$\Delta E (= 0.00061 \times 932) = 0.568\,\text{MeV}$;
$(= 0.568 \times 1.6 \times 10^{-13}) = 9.1 \times 10^{-14}\,\text{J}$; ***[3]***

(c) (i) the mass/amount of a sample;
activity A of the sample; ***[2]***

(ii) calculate the number of atoms N in the sample from the mass and the Avagadro constant;
use the relation $\frac{dN}{dt} = A = -\lambda N$ to find the decay constant;
calculate half-life from $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$; ***[3]***
*Award **[1]** for (c)(i) and **[2]** for (c)(ii) if mass or activity of argon at two separate times measured in (c)(i) and used to find $T_{\frac{1}{2}}$ from correct equation.*

Part 2 Friction

(a) nature of the surfaces;
normal reaction;
relative motion of the surfaces; ***[2 max]***

(b) friction is the frictional force between an object and a surface / two surfaces;
static friction is (the frictional force) when the object/surfaces are at rest;
dynamic friction is(the frictional force) when the object is sliding / one of the surfaces is sliding / moving with respect to the other;
some additional comment *e.g.* friction varies from zero to maximum / maximum value of static friction always greater than kinetic friction; ***[3 max]***
*Award **[1 max]** for an answer such as "friction force on an object at rest and friction force on a moving object". Some appreciation that it is friction between two surfaces is required.*

(c) $\mu_s = \left(\frac{7.2}{12}\right) = 0.60$; ***[1]***

(d) it will accelerate;
since the coefficient of dynamic friction is less than coefficient of static friction;
therefore, frictional force acting is less than 7.2 N / a net force greater than zero acting on the block; ***[3]***
*Award **[0]** for a bald statement or incorrect reasoning.*