SECTION A

A1. (a) a straight line / linear graph cannot be drawn that lies within all the error bars; ***[1]***

(b) smooth curve;
that does not go outside error bars; ***[2]***

(c) recognize that D_λ is the gradient of the graph;
suitable triangle $\Delta\lambda \geq 100$ nm;
to give magnitude $1.15-1.40\times10^{-5}\,\text{nm}^{-1}$ / $10^4\,\text{m}^{-1}$;
negative sign; ***[4]***

(d) (i) recognize that A is the intercept on the *n* axis;
line shown extrapolated;
$A = 1.6020(\pm0.0001)$; ***[3]***
*Award full marks for correct answer with omission of first marking point award **[2 max]** if they find the gradient (B) and then use a data point to calculate A.*

(ii) it is the value of *n* / refractive index for an infinite wavelength / $\lambda =$ infinity / minimum value of *n*; ***[1]***

A2. (a) the molecules gain energy by collision with the moving piston;
therefore average KE of the molecules increases;
temperature is a measure of average KE of the molecules (so temperature increases); ***[3]***
"Average kinetic energy" must appear once for full marks.

(b) $P_2 = \dfrac{1.0\times10^5\times0.20\times330}{300\times0.07}$;
$= 3.1\times10^5\,\text{Pa}$; ***[2]***
Award full marks for bald correct answer.

A3. (a) (i) $F = Mg\sin\theta$;
$= 960\times9.8\times0.26$;
2.4×10^3 N ***[2]***

(ii) $KE = \left(\dfrac{1}{2}mv^2\right) = (480\times81) = 3.9\times10^4\,\text{J}$; ***[1]***

(b) $KE = Fs$;
to give $F = 2.6\times10^3\,\text{N}$; ***[2]***
*Award **[1 max]** if $v^2 = 2as$ is used.*

(c) recognize that $KE = \text{mass} \times \text{sp ht} \times \text{rise in temperature}$;

$\Delta\theta = \dfrac{3.9 \times 10^4}{2 \times 900 \times 5.2}$;

$= 4.2\ \text{K}$;

Award full marks for bald correct answer.

no energy / heat loss to the surroundings / energy distributed evenly in shoe and drum; ***[4]***

SECTION B

B1. Part 1 Momentum and energy

(a) (impulse =) force × time for which force acts;
impulse $\left(F\Delta t\right) = $ change in momentum $\left(\Delta p\right)$; *[2]*

(b) *The following points are needed for maximum marks.*
from Newton 3;
when objects are in contact, the forces exerted by the objects on each other are equal and opposite;
from Newton 2 / collision time is the same;
impulses are equal and opposite;
therefore changes in momentum are equal and opposite / total change in momentum is zero;

or

Accept algebraic solution.
from Newton 3;
$F_{AB} = -F_{BA}$;
from Newton 2;
$F_{AB}\Delta t = m_{\mathrm{A}}\Delta v_{\mathrm{A}}$;
$= -m_B \Delta v_B$; *[5]*

(c) (i) $v = \sqrt{2gh}$;
to give $v = 2.2 \text{ m s}^{-1}$; *[2]*
Award full marks for bald correct answer.

(ii) from conservation of momentum / $V \times 5.2 \times 10^{-3} = 0.38 \times 2.2$;
$V = \dfrac{0.38 \times 2.2}{5.2 \times 10^{-3}}$;
to give $V = 160 \text{ m s}^{-1}$ *[2]*

B1. Part 2 Waves

(a) Transverse

the particles (of the medium) vibrate at right angles;
to the direction of energy transfer;

Longitudinal

the particles (of the medium) vibrate in the same direction as the direction of energy transfer; ***[3]***

(b) (i) time period = 0.13 s;

$\left(f = \frac{1}{T} = \frac{1}{0.13}\right) = 7.7\,(\pm 0.3)\text{ Hz}$; ***[2]***

Award full marks for bald correct answer.

(ii) 8 mm; ***[1]***

(c) $\lambda = \frac{v}{f}$;

$\frac{15}{7.7}$;

$\lambda = 1.95\text{ cm} \approx 2.0\text{ cm}$ ***[2]***

(d) start at $(-1.2 \rightarrow -2.0)$ on y-axis;
sine curve of amplitude 8 mm;
wavelength 2 cm; ***[3]***

(e) use of $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$

$\sin\theta_2 = \frac{v_2}{v_1}\sin\theta_1$;

$= \frac{20}{15}\sin 30$ to give $\theta_2 = 42^{\circ}$;

angle $= 48^{\circ}$; ***[3]***

B2. Part 1 Power

(a) the rate of working / $\frac{\text{work}}{\text{time}}$; *[1]*
Ratio or rate must be clear.

(b) let $\Delta s =$ distance moved in time Δt such that $v = \frac{\Delta s}{\Delta t}$;

$P = \frac{\text{work}}{\text{time}} = \frac{F\Delta s}{\Delta t}$;
$= Fv$ *[2]*
All symbols must be defined for full marks.

(c) (i) friction; *[1]*

(ii) <u>recognize that F = rate of change of momentum</u>;
$\left(= \frac{\Delta m}{\Delta t} v\right) = (60 \times 2.0) = 120$ N; *[2]*
Award full marks for bald correct answer.

(iii) $(P = 120 \times 2.0) = 240$ W; *[1]*

(iv) $K = \frac{1}{2}\frac{\Delta m}{\Delta t} v^2$;
$= \left(\frac{1}{2} \times 60 \times 4.0\right) = 120$ W; *[2]*
Award full marks for bald correct answer.

(v) the sand on the conveyor belt must slip to be accelerated;
in slipping kinetic energy is dissipated / lost as internal energy / heat in the sand and conveyor belt;

or

there is friction between the sand and conveyor belt;
therefore kinetic energy is dissipated / lost as internal energy / heat in the sand and conveyor belt; *[2]*
Award zero for bald statement "energy is lost as heat".

(d) $P_{\text{in}} = \left(\frac{P_{\text{out}}}{eff}\right) = \frac{240}{0.40}$;
$= 600$ W; *[2]*
Award full marks for bald correct answer.

B2. Part 2 Nuclear reaction

(a) (i) an atom or a nucleus that is characterized by the constituents of its nucleus / a particular type of atom or nucleus / *OWTTE*;
(in particular) by its proton (atomic) number and its nucleon number / number of protons and number of neutrons; ***[2]***

(ii) nuclides that have the same proton number but different nucleon number / same number of protons different number of neutrons; ***[1]***

(b) (i) beta; ***[1]***

(ii) 5.00216 MeV is equivalent to 0.00537 *u*;
$23.99096 = 23.98504 + 0.00537 + \text{rest of mass of particle}$;
rest mass = 0.00055 *u*; ***[3]***
No credit given for bald correct answer.

(c) sodium-24 has more nucleons;
and more nucleons (usually) means greater (magnitude of) binding energy;

or

sodium-23 has less nucleons;
and less nucleons (usually) means less (magnitude of) binding energy; ***[2]***

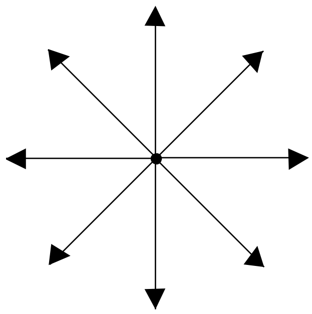
(d) (i) data points $t = T$, $2T$ and $3T$ corresponding to, $\frac{N_0}{2}$, $\frac{N_0}{4}$ and $\frac{N_0}{8}$ /
some indication of correct data points *i.e. N* values need not be written in;
Judge by eye.
best fit line through data points; ***[2]***

(ii) (from the) gradient / slope (at time *t*); ***[1]***

B3. Fields and electric charge associated with atoms

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

(b) (i)



at least 6 symmetric radial lines as shown <u>touching the proton</u>;
correct direction; ***[2]***

(ii) use of $E = k\dfrac{q}{r^2}$

$E = \dfrac{9.0\times10^{9}\times1.6\times10^{-19}}{25\times10^{-22}}$;

$= 5.8\times10^{11}\,\text{N C}^{-1}$; ***[2]***

Award full marks for bald correct answer.

(c) (i) use of $F = qE$

$F = 1.6\times10^{-19}\times5.8\times10^{11}$;

$= 9.3\times10^{-8}\,\text{N}$ ***[1]***

Allow use of force law.

(ii) recognize that $F = \dfrac{mv^2}{r}$;

$\dfrac{1}{2}mv^2 = \dfrac{1}{2}Fr$;

$= \dfrac{1}{2}\times9.3\times10^{-8}\times5.0\times10^{-11}$;

$= 2.3\times10^{-18}\ \text{J}$ ***[3]***

(iii) kinetic energy $= \dfrac{2.3\times10^{-18}}{1.6\times10^{-19}} = 14\ \text{eV}$;

PE = Total – KE;

= –28 (eV); ***[3]***

(d) (conduction) electrons have high random speeds;
when accelerated by an electric field inside a conductor / *OWTTE*;
although they collide (frequently) with lattice ions;
they obtain a net speed in the direction opposite to the field direction; ***[4]***

(e) the power supplied per unit current / the energy supplied per unit charge; ***[1]***

(f) (i) $R=\left(\frac{6.0}{0.2}\right)=30\,\Omega$; ***[1]***

(ii) $P=(6.0\times 0.2)=1.2\text{ W}$; ***[1]***

(g) (i) $I=\left(\frac{6.0}{15}\right)=0.40\text{ A}$; ***[1]***

(ii) total current in the circuit 0.60 A;
resistance of parallel circuit $=10\,\Omega$ / lost volts $=5.0\times 0.6$;

total resistance in circuit $=15\,\Omega$ / lost volts $=3\text{ V}$;
e.m.f. $=(0.60\times 15)=9\text{ V}$;

or

total current $=0.60\text{ A}$;
pd across $\text{R}=6.0\text{ V}$;
e.m.f. $=6.0+0.60\times 5.0$;
$=9.0\text{ V}$; ***[4]***