

SECTION A

- A1. (a) (i) reasonable curve drawn up to 15 ms^{-1} that does not go through zero; [1]
Expect smooth single-line within one square of each correctly plotted point.
- (ii) shape of curve wrong / curve does not go through zero; [1]
- (iii) $5\% = \pm 30$;
 correct drawing of error bar; [2]
- (b) (i) when $v_{\text{in}} = 14 \text{ ms}^{-1}$, $P_{\text{out}} = 570(\pm 20) \text{ kW}$;
 $P_{\text{in}} = 1250(\pm 50) \text{ kW}$;
Allow $\pm \frac{1}{2}$ a square.
 $\text{efficiency} = \frac{570}{1250} = 0.46 \text{ or } 46\%$; [3]
- (ii) the efficiency decreases;
 for a given increase in velocity the increase in P_{out} gets smaller;
 whereas the increase in theoretical P_{in} gets larger;
or
 as the P_{out} graph starts to flatten / *OWTTE*;
 the P_{in} graph steepens; [3]
- (c) *advantage*:
 wind is renewable so no resources used up / wind is free / no chemical pollution /
 carbon dioxide emission / does not add to the enhanced greenhouse effect;
disadvantage:
 expensive initial/capital costs / large land area needed / visual / noise pollution /
 winds unpredictable/not constant / affect on birds; [2]
Award any other suitable advantage or disadvantage.

SECTION A

- A2.** (a) measure activity A of a sample containing the isotope;
determine (chemically) the number N of atoms of the isotope (from the measured mass of the isotope);

$$A = \lambda N \quad \text{and} \quad T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}; \quad [3]$$

- (b) fraction = $\left(\frac{1}{2}\right)^{1.6}$ **or** fraction = $e^{-1.6 \times \ln 2}$;
fraction = 0.33;

[2]

- A3.** (a) curved line, starts at V_1 and same pressure as given line;
 always steeper than given line and finishing at V_2 and higher pressure than given line; [2]
Accept any line linking V_1 and V_2 provided it is steeper than the first line.
- (b) (i) upper line identified as G; [1]
 (ii) area between the lines shaded; [1]
- (c) *the gas:*
 entropy decreases;
 gas is at constant temperature and energy transferred to surroundings / (same number of moles of) gas molecules occupy reduced volume and therefore disorder (of gas) reduced;
the surroundings:
 entropy increases; [3]
- A4.** (a) e.m.f. induced proportional to/equal to;
 rate of change of flux (linkage) / rate of flux cutting; [2]
- (b) (i) for e.m.f./current to be induced in secondary, flux must be changing in the core;
 changing flux is caused by varying current in primary; [2]
 (ii) induced currents in core are kept small; (*do not allow reduced/prevented*)
 to reduce heating/energy losses; (*do not allow mere “eddy current losses”*) [2]
- (iii) use of $\frac{N_s}{N_p} = \frac{V_s}{V_p}$;
 to give $N_p = 8600$ turns;
 and $I_p \left(= \frac{42}{230} \right) = 180 \text{ mA}$; [3]

SECTION A

- A1.** (a) (i) $\pm 0.5^\circ\text{C}$; [1]
Do not accept 1°C .
- (ii) actual uncertainty = $\pm 70\Omega$;
 percentage uncertainty = $\left(\frac{70}{2600}\right) \times 100 = 3\%$; *(do not allow 2.7%)* [2]
Do not apply SD-1 here since the question asks specifically for an estimate.
- (b) (i) *at 20°C :* 1800Ω ; [1]
at 5°C : within range $3080\Omega \rightarrow 3220\Omega$;
 within $3120\Omega \rightarrow 3180\Omega$; [2]
- (ii) use of tangent at correct position clear;
 answer $64\Omega\text{K}^{-1}$ *or* $64\Omega^\circ\text{C}^{-1}$; *(allow $\pm 2\Omega\text{K}^{-1}$ *or* $\pm 2\Omega^\circ\text{C}^{-1}$)*
negative sign; [3]
- (c) gradient of graph decreases as temperature rises / increases as temperature drops; { *accept "gradient not constant".*
 so relationship cannot be linear; [2]
or
 straight-line joining extreme points;
 does not pass through "error boxes" of all points;
- (d) product RT calculated correctly for two points;
 product calculated correctly for third point;
 conclusion: not same value so suggestion not correct; [3]
Award [2 max] if $^\circ\text{C}$ used instead of K .

SECTION B

B1. Part 1 Units and momentum

(a) fundamental units are defined / arbitrarily / as a standard / are reproducible;
 derived units can be expressed in terms of the fundamental units; [1]
Both responses required to award the mark.

(b) (i) ms^{-1} ; [1]

(ii) derived units of momentum are kg ms^{-1} / units of R are the units of force;
 derived units of R are kg ms^{-2} ; [2]
Response needs correct statement of derived units.

(iii) kg m^{-1} ; [1]
ECF from answer in (b)(ii).

(c) (i) momentum is mass \times velocity; [1]

(ii) impulse is force \times time / change in momentum; [1]
In each case allow an equation, with symbols explained.

(d) (i) $\Delta p = 450 (18 - 13)$;
 $= 2250 \text{ kg ms}^{-1}$ [1]

(ii) idea of equating Δp to change in momentum of water;
 $m = \frac{2250}{19} = 118 \text{ kg } (\approx 120 \text{ kg})$; [2]

(iii) time of trolley in tank = $\frac{9.3}{15.5} = 0.60 \text{ s}$;
 $a = \frac{(18 - 13)}{0.60}$ *or* $\text{force} = \frac{2250}{0.60} (= 3750 \text{ N})$;
 $a = 8.3 \text{ ms}^{-2}$ $a = \frac{3750}{450} = 8.3 \text{ ms}^{-2}$; [3]

or

$$v^2 = u^2 + 2as;$$

$$a = \frac{13^2 - 18^2}{2 \times 9.3};$$

$$a = 8.3 \text{ ms}^{-2};$$

(e) (i) $E_k = \frac{1}{2}mv^2$;
 $= \frac{1}{2} \times 450 \times (18^2 - 13^2)$;
 $= 35000 \text{ J}$; [3]

(ii) $E_k = \frac{1}{2} \times 118 \times 19^2$
 $= 21000 \text{ J}$; (*allow 22 000 J for use of $m = 120 \text{ kg}$*) [1]

(f) some water will be thrown “sideways”;
this will account for the difference in the kinetic energies;
this will not have any momentum in the forward direction / equal masses of water to
left and right; [3]

SECTION B

B1. Part 1 Simple harmonic motion and the greenhouse effect

- (a) the force acting/accelerating (on the body) is directed towards equilibrium (position);
and is proportional to its/the bodies displacement from equilibrium; [2]
- (b) (i) $1.5 \times 10^{-10} \text{ m}$; [1]
- (ii) $T = 1.1 \times 10^{-12} \text{ s}$;
 $f = \left(\frac{1}{1.1 \times 10^{-12}} \right)$;
 $= 9.1 \times 10^{13} \text{ Hz}$ [2]
- (iii) $\omega = (2\pi f) = 5.7 \times 10^{14} \text{ (rad s}^{-1}\text{)}$;
 $E_{\text{max}} = \left(\frac{1}{2} m \omega^2 x_0^2 \right) = \frac{1}{2} \times 1.7 \times 10^{-27} \times (1.5)^2 \times 10^{-20} \times (5.7)^2 \times 10^{28}$;
 $= 6.2 \times 10^{-18} \text{ J}$ [2]
- (c) (i) $k = (4\pi^2 f^2 m_p) = 40 \times 83 \times 10^{26} \times 1.7 \times 10^{-27}$;
 $\approx 560 \text{ N m}^{-1}$ [1]
- (ii) use of $F = kx$ and $F = ma$;
to give $a = \frac{560 \times 1.5 \times 10^{-10}}{1.7 \times 10^{-27}} = 5.0 \times 10^{19} \text{ m s}^{-2}$; [2]
- (d) (i) infra red radiation radiated from Earth will be absorbed by greenhouse gases;
and so increase the temperature of the atmosphere/Earth; [2]
- (ii) the natural frequency of oscillation (of a methane molecule) is equal to
 $9.1 \times 10^{13} \text{ Hz}$;
because of resonance the molecule will readily absorb radiation of this
frequency; [2]

B2. Part 1 Latent heat and specific heat

- (a) (i) quantity of thermal energy/heat required to convert unit mass / mass of 1 kg of liquid to vapour/gas;
with no change of temperature / at its boiling point; [2]
- (ii) on vaporizing, potential energy of molecules/atoms increases;
on vaporizing, kinetic energy of molecules/atoms does not change;
only change in kinetic energy seen as change in temperature; [3]
The term “vaporizing” or “phase change” should be present at least once to award full marks.
- (b) (i) heater, variable resistor and power supply in series;
ammeter in series with heater, voltmeter in parallel with heater; [2]
- (ii) $P = VI$ used – not merely quoted;
 $I = \frac{80}{9} = 8.9 \text{ A};$ [2]
- (iii) idea of $\text{power} \times \text{time} = \text{mass} \times \text{latent heat}$;
allowance made in equation for heat loss to atmosphere;
 $(80 - 35) \times 60 = (1.89 - 0.70) \times L$;
 $L = 2300 \text{ J g}^{-1}$; [4]
*Award [3 max] for use of two powers and a reference to heat loss to atmosphere/environment to explain the difference in numerical values of L.
Award [2 max] for use of two powers and taking an average.
Award [1 max] for use of one power only.*
- (c) (i) $\text{mass} = (650 - 350) \times 6 \times 1 = 1800 \text{ g};$ [1]
- (ii) $\text{energy} = 1.8 \times 4.2 \times 10^3 \times (100 - 18);$
 $= 6.2 \times 10^5 \text{ J}$ [1]
Award mark for the substitution, not the final answer.
- (iii) $\text{cost} = \frac{6.2 \times 10^5 \times 365 \times 3.5}{1.0 \times 10^6};$
 $= 790 \text{ cents};$ [2]

B2. Part 2 Force fields

- (a) (i) *at A: constant;*
at B: decreasing; [2]
- (ii) field line gives the direction of the force (on mass or charge);
if lines touched (or crossed), particle would move in two directions at the same
time and this is impossible; [2]
- (iii) pattern is the same in all four quadrants *i.e.* symmetry;
correct pattern in one quadrant;
field directions correct; [3]
- (b) (i) must be a force normal to direction of motion / some reference to circular
motion;
so field is magnetic; $\left\{ \begin{array}{l} \textit{Do not award if there is no reasoning} \\ \textit{or reasoning is fallacious or misleading.} \end{array} \right.$ [2]
- (ii) particles are oppositely charged; [1]
- (iii) $r = \frac{mv}{Bq}$;
speed is decreasing / particle losing energy;
hence radius is decreasing; $\left\{ \begin{array}{l} \textit{Do not award if there is no reasoning} \\ \textit{or reasoning is fallacious or misleading.} \end{array} \right.$ [3]

B3. Part 1 Wave phenomena

- (a) (i) C shown where graph line cuts x -axis; [1]
- (ii) time period = 0.30 ms;
 use of $v = f\lambda$ and $f = \frac{1}{T}$ **or** $v = \frac{\lambda}{T}$;
 $\lambda = 380 \times 0.30 \times 10^{-3} = 0.11 \text{ m}$; [3]
ECF if time period misread.
- (b) (i) superposition of two waves / *OWTTE*;
 of same frequency and amplitude travelling in opposite directions; [2]
- (ii) stationary/standing wave is set up in the tube;
 heaps form at the (displacement) nodes / powder pushed away from antinodes; [2]
- (iii) wavelength = $(2 \times 9.3 =) 18.6 \text{ cm}$;
 speed = $(1800 \times 0.186 =) 330 \text{ m s}^{-1}$; [2]
ECF if value of wavelength wrong.
- (c) heaps further apart means longer wavelength;
 hence speed increases (as temperature rises); $\left\{ \begin{array}{l} \text{Do not award if there is no reasoning or} \\ \text{reasoning is fallacious or misleading.} \end{array} \right.$ [2]
- (d) (i) when two waves meet;
 resultant displacement found by summing individual displacements;
 to give maximum displacement / displacement greater than that of an individual
 wave; [3]
- (ii) line in correct position, labelled C; [1]
- (iii) line in correct position, labelled D; [1]
- (e) use of $\lambda = \frac{ax}{D}$ and $a = 4.0 \times 10^{-2} \text{ m}$;
 $\lambda = \frac{4.0 \times 10^{-2} \times 1.2}{1.5}$;
 $\lambda = 3.2 \times 10^{-2} \text{ m}$; [3]
ECF if value of "a" wrong [2 max].

B3. Part 2 Nuclear decay

- (a) emission of particles and/or e.m. radiation from unstable nucleus;
 not affected by temperature/environment / is spontaneous process;
 constant probability of decay (per unit time) / is random process;
 activity/number of unstable nuclei in sample reduces exponentially;
 daughter nucleus is (energetically) more stable; [3 max]
- (b) (i) fission; [1]
- (ii) **N.B.** positions may be marked on line or on x -axis.
 U shown near right-hand end of line;
 Sr and Xe shown between U and the peak with Sr to the left of Xe; [2]
- (iii) total binding energy of uranium = $1189 + 784.8 - 187.9$;
 $= 1785.9 \text{ MeV}$;
 binding energy per nucleon = $\left(\frac{1785.9}{235} \right) = 7.60 \text{ MeV}$; [3]
Allow unit as MeV or MeV per nucleon.
Accept answer in Joules e.g. $1.22 \times 10^{-12} \text{ J}$.
- (iv) binding energy is zero because neutrons are separate particles; [1]