

**SECTION A**

- A1.** (a) correct placing of both error bars; [1]  
*Total error bar length 3 to 5 squares.*  
*Be generous as the error bars are a bit difficult to place.*
- (b) (i) a straight line can be drawn; [2]  
 that passes through the error bars;  
*Notice that first point may be implicit, for example, if they have drawn a straight-line of best fit.*
- (ii) slope =  $-1.0$ ; (*accept answers in the range  $-0.95$  to  $-1.1$  and ignore any units*)  
 intercept =  $1.85$ ; (*accept answers in the range of  $1.75$  to  $1.90$* )  
 correct statement of equation e.g.  $\frac{R}{R_s} = 1.85 - 1.0 \times \frac{M}{M_s}$ ;  $\left\{ \begin{array}{l} \text{accept e.g.} \\ R = 1.85 - 1.0 \times M \end{array} \right.$  [3]
- (iii)  $1.85 M_s$ ;  $\left\{ \begin{array}{l} M_s \text{ unit needed. Accept answers in the range } 1.6 M_s \text{ to } 2.0 M_s, \\ \text{i.e. consistent with a line of best-fit} \end{array} \right.$  [1]
- (c) the maximum mass corresponds to a star of zero radius/ $R=0$ , so it is unphysical /  
 radius is zero/too small; [1]
- (d) (i) smooth curve through data points; [1]
- (ii)  $1.4 M_s$  / consistent with any line of best-fit even if straight; [1]  
*Do not penalize absence of unit  $M_s$  if already penalized earlier.*
- (iii) answers based on an extrapolation from a curve which is imprecise; [1]  
*The idea is to see a comment about extrapolation outside the data range so plain references to uncertainties in general should not be accepted.*

- A2.** (a) satisfies  $pV = nRT$  (at all  $p$ ,  $V$  and  $T$ ) / point molecules / no intermolecular forces; [1]  
 Allow any other kinetic theory assumption.
- (b) (i) the (total random) kinetic energy of the molecules (of the gas); [1]
- (ii) the (absolute kelvin) temperature is proportional to/is a measure of the average kinetic energy of the molecules of the gas; and hence the internal energy is proportional to the temperature (and the total number of molecules in the gas) /  $U \propto NT$ ; [2]  
 Do not accept  $T$  increases  $U$  increases. Award [0] for any reference to potential energy.
- (c) (i)  $2.0 \times 10^5$  Pa; [1]
- (ii) correct positioning of point on graph; [1]
- (iii) concave curve (hyperbola) joining A to B; (judged by eye) [1]  
 Do not check points, general shape of curve only.
- A3.** (a) the rocket exerts a force on the gases and so the gases exert a force on the rocket / there is a reaction force on rocket from gases / *OWTTE*; force on the rocket causes the rocket to accelerate; [2]
- (b) the net external force on the rocket and gases/system is zero / system is closed/isolated, therefore the total momentum of the system stays the same; change in momentum of the gases = (–) change in momentum of the rocket; [2]
- (c) after 1.0s momentum of gases =  $1.4 \times [7.2 \times 10^3 - v]$  Ns and momentum of rocket =  $(280 - 1.4) \times v$  Ns;  
 application of momentum conservation  $\left( \text{to give } v = \frac{1.4 \times 7.2 \times 10^3}{280} \right)$ ;  
 $36 \text{ ms}^{-1}$ ; [3]

**SECTION B**

**B1. Part 1** Wave motion

(a) (i) 1.5 mm; [1]

(ii) 8.0 cm; [1]

(iii) distance travelled in 0.20 s is 3.2 cm;  
so speed is  $\left(\frac{3.2 \times 10^{-2}}{0.20}\right) = 0.16 \text{ m s}^{-1}$ ; [2]

(iv)  $f = \frac{0.16}{8.0 \times 10^{-2}} = 2.0 \text{ Hz}$ ; [1]

(b) travelling waves transfer energy (standing waves do not);  
travelling waves have a constant amplitude (standing waves do not);  
standing waves have points that always have zero displacement (travelling waves do not);  
the phase of a travelling wave constantly changes (but in standing waves points in between consecutive nodes have constant phase); [2 max]

(c) (i) it is the speed of energy transfer/rate/speed at which wavefronts move forward; [1]

(ii) a standing wave is formed from the superposition of two travelling waves;  
wave speed refers to the speed of the travelling waves; [2]

(d) (i) the oscillating string collides with the air molecules surrounding it;  
creating a pressure/longitudinal wave; [2]

(ii) wavelength of wave on string is  $2 \times 0.80 = 1.6 \text{ m}$ ;  
frequency is then  $\left(\frac{240}{1.6}\right) = 150 \text{ Hz}$ ;  
sound has the same frequency and so wavelength is  $\left(\frac{340}{150}\right) = 2.3 \text{ m}$ ; [3]

*Award [1 max] for those using a wavelength of 0.80m obtaining a wavelength of 1.1m in air. Accept alternative derivations that use a ratio and do not calculate the frequency explicitly.*



**B2. Part 1**      Mechanics

(a) (i)  $\frac{350}{9.8} = 36 \text{ kg};$  (*accept 35 kg*) [1]

(ii) girl took 0.5 s to fall;  
so  $v = gt = (9.8 \times 0.5) = 4.9 \text{ ms}^{-1};$  (*accept 5.0 ms<sup>-1</sup>*) [2]

(iii)  $h = \frac{1}{2}gt^2$   
 $= \frac{1}{2}(9.8 \times 0.50^2);$   
 $= 1.2 \text{ m};$  (*accept 1.3 m*) [2]

**or**

use of conservation of energy to get

$$\frac{1}{2}mv^2 = mgh \Rightarrow h = \frac{v^2}{2g};$$

$$h = \frac{4.9^2}{2 \times 9.8} = 1.2 \text{ m};$$
 (*accept 1.3 m*)

(iv) maximum force on girl = 1400 N;  
so maximum acceleration =  $\frac{1400}{36} = 39 \text{ ms}^{-2};$  (*accept 40 ms<sup>-2</sup>*) [2]

(b) (i) the net force is still in the downward direction / the trampoline force is less than the weight / the trampoline has not yet deflected enough to give rise to a force larger than the weight;  
and so the girl keeps accelerating downwards; [2]

(ii) the change in momentum = area under graph from point C to point D;  
 $= \frac{1}{2} \times 350 \times (0.53 - 0.50);$   
 $\approx 5 \text{ N s}$  [2]

(iii)  $36 \times (v_{\text{max}} - 4.9) = 5 \text{ N s};$   
so  $v_{\text{max}} = 5 \text{ ms}^{-1};$  [2]

**Part 2** Radioactivity

- (a) (i) nuclei with the same atomic number but different mass number; [1]
- (ii) identification of a proton/ ${}^1_1\text{H}/\text{p}$ ;  
 correct equation *i.e.*  ${}^1_0\text{n} + {}^{14}_7\text{N} \rightarrow {}^1_1\text{p} + {}^{14}_6\text{C}$ ; [2]
- (b)  ${}^{14}_6\text{C}$  is unstable while  ${}^{12}_6\text{C}$  is stable;  
 neither  ${}^{14}_6\text{C}$  nor  ${}^{12}_6\text{C}$  may be replenished (through food/breathing as in an animal that is alive) after bone is dead;  
 ${}^{14}_6\text{C}$  decays, decreasing its concentration in the bone; [2 max]
- (c) (i)  $1.3 \times 10^{-12}$ ; [1]
- (ii) evidence of locating the point in the graph with  $F$  value half of the initial;  
 to get half-life 5700 ( $\pm 100$ ) years; [2]
- (d) evidence of locating the point in the graph with  $F$  value  $0.6 \times 10^{-12}$ ;  
 to get age = 6400 ( $\pm 100$ ) years; [2]
- (e) the dinosaur bone has been dead for millions of years;  
 the  $F$  value is negligibly small/too small to be measured with any accuracy /  
 $F$  value in atmosphere might have varied; [2]

**B3. Part 1** Calorimetry

- (a) energy required to increase the temperature by 1 degree; [1]
- (b) (i) change in temperature of calorimeter is  $6.0^{\circ}\text{C}$ ;  
and so  $Q = (950 \times 6) = 5.7 \times 10^3 \text{ J}$ ; [2]
- (ii) change in temperature of copper block is  $72^{\circ}\text{C}$ ;  
and so  $C = \left( \frac{5.7 \times 10^3}{72} \right) = 79 \text{ J K}^{-1}$ ; [2]
- (c) the mass of the block; [1]
- (d) *Any two suitable suggestions.*  
the temperature of the block may not be  $100^{\circ}\text{C}$ ;  
some boiling water may be transferred to the calorimeter;  
the calorimeter is not perfectly insulated; [2 max]

**Part 2** Electricity and magnetism

(a) work done per unit charge in moving charge completely around the circuit / power supplied per unit current; [1]

(b) (i) two sets of series resistors at  $90\ \Omega$  each;  
and these are in parallel for a total of  $45\ \Omega$ ;  
plus the internal resistance in series for a grand total of  $50\ \Omega$ ; [3]

(ii) total current is  $I = \left(\frac{12}{50}\right) = 0.24\ \text{A}$ ; [1]

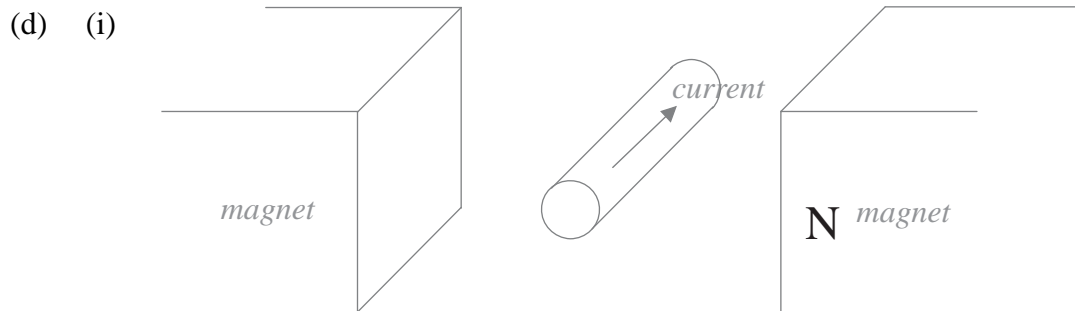
*Watch for ECF if answer for resistance is wrong.*

(iii)  $P_{\text{total}} = EI$ ;  
 $= (12 \times 0.24) = 2.9\ \text{W}$ ; [2]

*Watch for ECF if answer for current is wrong.*

(iv) across  $30\ \Omega$  voltage drops by  $3.60\ \text{V}$  (so potential at X is  $3.60\ \text{V}$ );  
across  $60\ \Omega$  voltage drops by  $7.20\ \text{V}$  (so potential at Y is  $7.20\ \text{V}$ );  
so potential difference between X and Y is (negative)  $3.6\ \text{V}$ ; [3]

(c) in the original circuit there is no current between X and Y / the resistance between X and Y is infinite;  
introducing a real voltmeter changes the total resistance of the circuit / allows current between X and Y / the resistance between X and Y is no longer infinite; [2]



because the magnetic force on the rod must be vertically upward and the law for the magnetic force requires field directed to the left, hence right pole is N; [1]

(ii)  $0.20 \times I \times 0.80 = 4.0$ ;  
and so  $I = 25\ \text{A}$ ; [2]

(iii) at Y;  
the magnetic fields of the wire and of the magnet add; [2]  
*Award [0] for a correct answer with no explanation or with an incorrect explanation.*

*Watch for ECF in case they got the polarity of the magnets wrong earlier in which case the answer is X.*