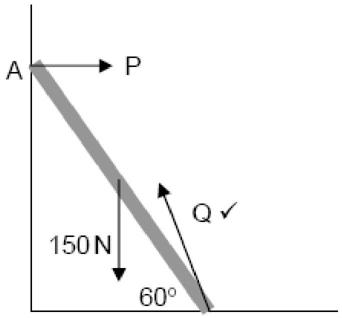
Jun 07 P2

Question 1		
(a)	gradient (or slope or steepness) is changing ✓ **or** graph a curve (**or** not a straight line)	**1**
(b)	25 ± 3 m ✓	**1**
(c)	(use of *speed* = *distance* ÷ *time* gives) speed = 100 ÷ 11 speed = 9.1 ± 0.2 m s^{-1} ✓	**1**
(d) (i)	constant acceleration ✓ **or** acceleration stays the same **or** velocity increases uniformly with time	**3**
(ii)	(use of $s = ut + ½ at^2$ gives) $a = 2 \times 100 \div (11^2)$ ✓ $a = 1.7$ m s^{-2} ✓	
	Total	**6**

Question 2		
(a) (i)	to balance (**or** oppose) the weight ✓ **or** stop ladder moving downwards	**2**
(ii)	to balance P ✓ **or** stop slipping or stop ladder moving right	
(b)	 correct arrow ✓	**1**
(c) (i)	43 N ✓	**2**
(ii)	150 N ✓	
(d)	increases (in magnitude) ✓ as greater downward force (**or** vertical component increase) ✓ direction moves closer to vertical ✓	**3**
	Total	**8**

Question 5		
(i)	find students weight (**or** mass) ✓ measure (vertical) height (of stairs) ✓ time (how long it takes student to run up stairs) ✓	**8**
(ii)	using $E_p = mgh$ ✓ link measurements to quantities used to calculate E_p ✓ divide gain in E_p (**or** work) by time to get power ✓	
(iii)	not all work done goes to E_p ✓ ignoring gain in E_k ✓ **or** ignoring movement **or** ignoring fiction **or** athlete gets hot **or** body not 100% efficient	
	Total	**8**

<table>
<tr><th>Question 6</th><th></th><th></th></tr>
<tr><td>(a)</td><td>for a body in equilibrium (or for a stationary body) ✓
the sum of the clockwise moments about any point is equal to the sum of the anti-clockwise moments ✓ (about the same point)</td><td>2</td></tr>
<tr><td>(b) (i)</td><td><table><tr><th>weight of object A/N</th><th>weight of object B/N</th><th>weight of object C/N</th><th>weight of object D/N</th></tr><tr><td>0.40</td><td>0.40 ✓</td><td>0.70 ✓</td><td>0.10</td></tr></table></td><td>5</td></tr>
<tr><td>(ii)</td><td>(use of $F_1 \times d_1 = F_2 \times d_2$ gives)
$0.70 \times d = 0.10 \times 0.08$ ✓
$d = 0.011$ m ✓</td><td></td></tr>
<tr><td>(iii)</td><td>T = 0.40 + 0.40 = 0.80 N ✓</td><td></td></tr>
<tr><td>(c) (i)</td><td>beam (holding B) turns clockwise ✓
or beam tips right
or moves up</td><td>3</td></tr>
<tr><td>(ii)</td><td>beams falls ✓</td><td></td></tr>
<tr><td>(iii)</td><td>(main) beam rotates clockwise ✓
or beam tips right
all due to because of unbalanced moment ✓
(explanation can be attached to any answer)
(all three rotations correct 2 max, two rotations correct 1 mark)</td><td></td></tr>
<tr><td></td><td>Total</td><td>10</td></tr>
</table>

Jun 06 P2

Question 2		
(a)	potential energy to kinetic energy ✓ mention of thermal energy and friction ✓	**2**
(b)	(use of $\frac{1}{2}mv^2 = mgh$ gives) $\frac{1}{2}v_h^2 = 9.81 \times 1.5$ ✓ $v_h = 5.4(2)\,\text{m s}^{-1}$ ✓ (assumption) energy converted to thermal energy is negligible ✓	**3**
(c)	component of weight down the slope causes acceleration ✓ this component decreases as skateboard moves further down the slope ✓ air resistance/friction increases (with speed) ✓	**max 2**
(d) (i)	distance (= 0.42×5.4) = 2.3 m ✓ (2.27 m) (allow C.E. for value of v_h from (b))	**5**
(ii)	$v_v = 9.8 \times 0.42$ ✓ $= 4.1(1)\,\text{m s}^{-1}$ ✓	
(iii)	$v^2 = 4.1^2 + 5.4^2$ ✓ $v = 6.8\,\text{m s}^{-1}$ ✓ ($6.78\,\text{m s}^{-1}$) (allow C.E. for value of v_h from (b))	
	Total	**12**

Question 3		
(a)	resultant force zero ✓ resultant torque about any point zero ✓	**2**
(b) (i)	force due to wire P = 5.0 − 2.0 = 3.0 N ✓	**3**
(ii)	(moments give) $5.0 \times d = 2.0 \times 0.90$ ✓ $d = 0.36\,\text{m}$ ✓	
	Total	**5**

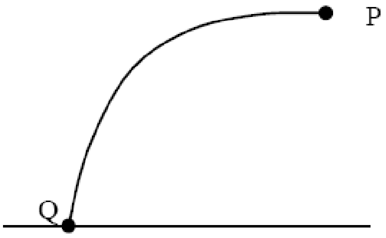
Jun 05 P2

Question 3		
(a)	weight/gravity causes raindrop to accelerate/move faster (initially) ✓ resistive forces/friction **increase(s)** with **speed** ✓ resistive force (eventually) equals weight ✓ [or upward forces equal downward forces] resultant force is now zero ✓ [or forces balance or in equilibrium] no more acceleration ✓ [or correct application of Newton's Laws] [if Newton's third law used, then may only score first two marks]	**Max 4**
(b) (i)	E_k (= $\frac{1}{2} mv^2$) = $\frac{1}{2} \times 7.2 \times 10^{-9} \times 1.8^2$ ✓ $= 1.2 \times 10^{-8}$ J ✓ (1.17×10^{-8} J)	**4**
(ii)	work done (= mgh) = $7.2 \times 10^{-9} \times 9.81 \times 4.5$ ✓ $= 3.2 \times 10^{-7}$ J ✓ (3.18×10^{-7} J)	
(c)	$v_{\text{resultant}} = \sqrt{(1.8^2 + 1.4^2)}$ ✓ $= 2.2(8)\,\text{m s}^{-1}$ ✓ $\theta = \tan^{-1}(1.4/1.8) = 38°$ ✓ (37.9°) [or correct scale diagram]	**3**

Jun 04 P2

1

(a)(i)



✓

(ii) no **horizontal** force acting ✓
(hence) no (horizontal) acceleration ✓
[or correct application of Newton's First law] *(3)*

(b)(i) (use of $v^2 = u^2 + 2as$ gives) $32^2 = (0) + 2 \times 9.81 \times s$ ✓
$s = \frac{1024}{19.62}$ ✓ (= 52.2 m)

(ii) (use of $s = ½at^2$ gives) $52 = ½ 9.81 \times t^2$ ✓
$t = \sqrt{\left(\frac{104}{9.81}\right)} = 3.3$ s ✓ (3.26 s)
[or use of $v = u + at$ gives $32 = (0) + 9.81 \times t$ ✓
$t = \frac{32}{9.81} = 3.3$ s ✓ (3.26 s)]

(iii) (use of $x = vt$ gives) x (= QR) = 95 × 3.26 ✓
= 310 m ✓
(use of $t = 3.3$ gives $x = 313.5$ m)
(allow C.E. for value of t from (ii)) *(6)*

(c) maximum height is greater ✓
because vertical acceleration is less ✓
[or longer to accelerate] *(2)*
(11)

3

(a) product of the force and the **perpendicular distance** ✓
reference to a point/pivot ✓ (2)

(b)(i) since *W* is at a greater distance from A ✓
then *W* must be less than *P* if moments are to be equal ✓

(ii) *P* must increase ✓
since moment of girl's weight increases as she moves from A to B ✓
correct statement about how P changes
(e.g. P minimum at A, maximum at B, or P increases in a linear fashion) ✓ max *(4)*
(6)

2

(a)(i) (gravitational) potential energy to kinetic energy ✓

(ii) kinetic energy to heat energy
[or work done against friction] ✓ (*2*)

(b) e.g. when using light gates
place piece of card on trolley of measured length ✓
card obscures light gate just before trolley strikes block ✓
calculate speed from length of card/time obscured ✓

alternative 1: measured <u>horizontal distance</u> ✓
speed = distance/time ✓
time ✓

alternative 2: measure h ✓
equate potential and kinetic energy ✓
$v^2 = gh$ ✓

alternative 3: data logger + sensor ✓
how data processed ✓
how speed found ✓ (*3*)

(c) vary starting height of trolley
[or change angle] ✓
the greater the height the greater the speed of impact ✓

[or alter friction of surface ✓
greater friction, lower speed ✓] <u>(*2*)</u>
<u>(*7*)</u>

3

(i) weight greater than air resistance
[or (initially only) weight/gravity acting] ✓
hence resultant force downwards or <u>therefore</u> acceleration (2nd law) ✓
air resistance or upward force increases with speed ✓
until air resistance equals weight or resultant force is zero ✓
leaf moves at constant velocity (1st law)
[or 1st law applied correctly] ✓

(ii) air resistance depends on shape
[or other correct statement about air resistance] ✓
air resistance less significant ✓
air resistance less, therefore greater velocity
[or average velocity greater
or accelerates for longer] ✓ $_{\text{max}}$<u>(*5*)</u>
<u>(*5*)</u>

4

(a)(i) horizontal component of the tension in the cable ✓

(a)(ii) vertical component of the tension in the cable ✓ (*2*)

(b)(i) $T_{\text{vert}} = 250 \times 9.81 = 2500$ N ✓ (2452 N)

(b)(ii) $T_{\text{horiz}} = 1200$ N ✓

(b)(iii) $T^2 = (1200)^2 + (2500)^2$ ✓
$T = (1.44 \times 10^6 + 6.25 \times 10^6)^{1/2} = 2800$ N ✓ (2773 N)
(if use of $T_{\text{vert}} = 2450$ N then $T = 2730$ N)
(allow C.E. for values from (b)(i) and (b)(ii))

(b)(iv) $\tan\theta = \dfrac{1200}{2500}$ ✓
$\theta = 26^\circ$ ✓
(allow C.E. for values from (b)(i) and (b)(ii)) (*6*)

(*8*)

Jan 07 P2

Question 3			
(a) (i)	(use of $F_H = F\cos\theta$ gives) resultant force = 2 × 6500 cos 35 resultant force = 11 000 N (10 649) (1 out of 2 if only one component given)	✓✓	**4**
(ii)	(use of work = force × distance gives) work = 11 000 × 1.5 × 60 work = 990 000 J (958 408) (if use 10 649 then 960 000 J)	✓✓	
(b)	there is an opposing force **or** mention of friction/drag work is done on this force **or** overall resultant force is zero	✓✓	**2**
(c)	initially accelerates as horizontal component increases (so) forward force now larger than drag **or** resultant force no longer zero **or** now a resultant forward force eventually reaches new higher constant speed	✓✓✓	**max 3**
		Total	**9**

Jan 06 P2

Question 1		
(a)	scales ✓ six points correctly plotted ✓ trendline ✓	**3**
(b)	average acceleration = $\frac{26}{25}$ ✓ = 1.0(4) m s^{-2} ✓ (allow C.E. for incorrect values used in acceleration calculation)	**2**
(c)	area under graph ✓ = 510 ± 30 m ✓	**2**
(d)	(graph to show force starting from *y*-axis) decreasing (not a straight line) ✓ to zero (at end of graph) ✓	**2**
(e)	(since) gradient of a velocity-time graph gives acceleration ✓ first graph shows acceleration is decreasing ✓	**2**
	Total	**11**

Jan 06 P3

Question 5			
(a)		tensile stress: (normal) force per unit cross-sectional area ✓ tensile strain: ratio of extension to original length ✓	**2**
(b)	(i)	loading: obeys Hooke's law from A to B ✓ B is limit of proportionality ✓ beyond/at B elastic limit reached ✓ beyond elastic limit, undergoes plastic deformation ✓ unloading: at C load is removed linear relation between stress and strain ✓ does not return to original length ✓	**Max 9**
	(ii)	ductile ✓ permanently stretched ✓ [or undergoes plastic deformation or does not break]	
	(iii)	AD: permanent strain (or extension) ✓	
	(iv)	gradient of the (straight) line AB (or DC) ✓	
	(v)	area under the graph ABC ✓	
(c)		$E = \frac{Fl}{Ae}$ ✓ $e = \frac{75 \times 3.0}{2.8 \times 10^{-7} \times 2.1 \times 10^{11}}$ = 3.8(3) mm ✓	**2**
		Total	**13**

Jun 05 P3

Question 5		
(a)	Hooke's law: the extension is proportional to the force applied ✓ up to the limit of proportionality or elastic limit [or for small extensions] ✓	**2**
(b) (i)	(use of $E = \frac{F}{A}\frac{l}{e}$ gives) $e_s = \frac{80\times0.8}{2.0\times10^{11}\times2.4\times10^{-6}}$ ✓ $= 1.3 \times 10^{-4}$ (m) ✓ (1.33×10^{-4} (m)) $e_b = \frac{80\times1.4}{1.0\times10^{11}\times2.4\times10^{-6}} = 4.7 \times 10^{-4}$ (m) ✓ (4.66×10^{-4} (m)) total extension = 6.0×10^{-4} m ✓	**7**
(ii)	$m = \rho \times V$ ✓ $m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3}$ (kg) ✓ $m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3}$ (kg) ✓ (to give total mass of 44 or 43.8×10^{-3} kg)	
(c)	(use of $m = \rho A l$ gives) $l = \frac{44\times10^{-3}}{8.5\times10^{3}\times2.4\times10^{-6}}$ ✓ $= 2.2$ m ✓ (2.16 m) (use of mass = 43.8×10^{-3} kg gives 2.14 m)	**2**

Jun 06 P3

Question 5		
(a) (i)	the extension produced (by a force) in a wire is directly proportional to the force applied ✓ applies up to the limit of proportionality ✓	**5**
(ii)	elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) ✓ [or correct use of permanent deformation]	
(iii)	the Young modulus: ratio of tensile stress to tensile strain ✓ unit: Pa or N m^{-2} ✓	
(b) (i)	length of wire ✓ **diameter** (of wire) ✓	**6**
(ii)	graph of force vs extension ✓ reference to gradient ✓ gradient = $E\frac{A}{l}$ ✓ [or graph of stress vs strain, with both defined reference to gradient gradient = E] area under the line of F vs e ✓ [or energy per unit volume = area under graph of stress vs strain]	
	Total	**11**

Jun 07 P3

Question 6		
(a) (i)	**max 5 for (i) from:** (wire can be horizontal or vertical) add a mass to the holder ✓ measure extension ✓ description of how extension is measured ✓ add further masses, measuring extension each time ✓ repeat measurements with decreasing masses ✓ measure (original) length of wire ✓	**max 8**
(ii)	(use of $E = \frac{F}{A}\frac{l}{e}$ to give) graph of (*mass/weight/force/tension/load*) vs *extension* ✓ (or *stress* vs *strain*) definition of quantity on *y* axis ✓ *E* from correct gradient ✓ of straight line ✓	
(b) (i)	in the equation $E = \frac{F}{A}\frac{l}{e}$, F, l and e are same for both wires ✓ (rearranging with) correct deduction ✓	**4**
(ii)	2 × 10^{11} = $\frac{F \times 2.5}{1.6\times10^{-7}\times4.8\times10^{-3}}$ ✓ F = 61 N ✓ (61.4 N)	
	Total	**12**

Jan 05 P1

Question 6

(a) $c_g \left(= \frac{c_a}{n}\right) = \frac{3\times10^8}{1.5}$ ✓
$= 2.0\times10^8\,\mathrm{m\,s^{-1}}$ ✓ (2)

(b)(i) $\sin\theta_1 \; (= n\sin\theta_2) = 1.5\times\sin 15$ ✓
$\theta_1 = 23°$ ✓ (22.8°)

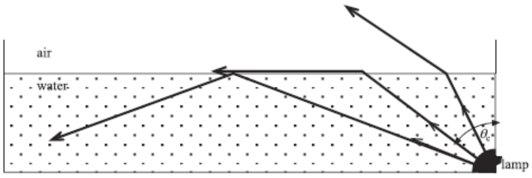
(ii) use of $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ ✓ (or equivalent)
$n_2 = \frac{1.5\times\sin 60}{(\sin 90)}$ ✓
$= 1.3$ ✓ (5)

(c) total internal reflection at A ✓
correct refraction out of glass at r.h. surface ✓ (same angles as l.h. side) (2)
(9)

Jan 06 P1

Question 5		
(a) (i)	(use of $n = \frac{\sin\theta_1}{\sin\theta_2}$ gives) $1.45 = \frac{\sin\theta_1}{\sin 15.5°}$ ✓ $\theta_1 = 22.8°$ ✓	**7**
(ii)	$n = \frac{1}{\sin\theta_c}$ ✓ $n = \left(\frac{1}{\sin 38.7°}\right) = 1.6(0)$ ✓	
(iii)	use of ${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2}$ and ${}_1n_2 = \frac{n_2}{n_1}$ ✓ [or $n_1 \sin\theta_1 = n_2 \sin\theta_1$] $1.45 \sin\theta_3 = 1.60 \sin 51.3$ ✓ $\theta_3 = 59.4°$ ✓ (allow C.E. for value of n from (ii))	
(b)	block 1 ✓(requires some explanation) reference to $\frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$ ✓ [or statement such as light refracts/bends towards normal as it enters a denser/higher refractive index material, or block 1 has lower refractive index]	**2**
(c)	reflection at boundary with i = r ✓ refraction (at bottom surface) bending away from normal ✓	**2**
	Total	**11**

Jan 07 P1

Question 6		
(a) (i)	use of n_w = speed of light in air/speed of light in water ✓ c_w (= 3.00 × 10^8/1.33) = 2.26 × 10^8 ms^{-1} ✓	**3**
(ii)	use of $n = 1 / \sin\theta_c$ θ_c (= $\sin^{-1}$(1 / 1.33)) = 48.8° ✓	
(b)	 mark for each ray ✓✓✓	**3**
(c)	the critical angle (for water-oil boundary) is larger ✓ there is a smaller difference between the refractive index of the oil and water than there is between the air and water ✓	**2**
	Total	**8**

Jun 06 P1

Question 3			
(a)		$n = \left(\frac{\sin\theta_1}{\sin\theta_2}\right) = \frac{\sin 15.0°}{\sin 10.0°}$ ✓ (= 1.49)	**1**
(b)		TIR on hypotenuse **and** refraction at top surface ✓ 55°, 10° and 15° all marked correctly ✓	**2**
(c)	(i)	use of $_1n_2 = \frac{\sin\theta_1}{\sin\theta_2}$ and $_1n_2 = \frac{n_2}{n_1}$ [or $n_1 \sin\theta_1 = n_2 \sin\theta_2$] ✓ 1.49 sin 55° = 1.37 sin θ_2 ✓ θ_2 = 63° ✓	**7**
	(ii)	(use of $n = \frac{c_1}{c_2}$) gives $1.37 = \frac{3.0\times10^8}{c_2}$ ✓ $c_2 = 2.2 \times 10^8$ m s^{-1} ✓ (2.19×10^8 m s^{-1})	
	(iii)	refraction at boundary between prisms, refracted away from normal ✓ emerging ray (r.h. vertical face) refracting away from normal ✓	
		Total	**10**

Jan 07 P4

Question 1			
(a)	(i)	$\lambda = \left(\frac{ws}{D}\right) = \frac{2.0\times3.2}{16} = 0.40$ m ✓	**2**
	(ii)	c (= $f\lambda$) = 850 × 0.40 = 340 ms^{-1} ✓	
(b)	(i)	speakers act as coherent sources or have constant phase relation ✓ light is emitted from sources in (incoherent) bursts ✓ light sources are not coherent or phase relation not constant ✓	**max 5**
	(ii)	use of double slit ✓ wavefronts are divided at slits ✓ slits act as coherent sources ✓ slit sources have the same frequency ✓ slit sources have a constant phase relation ✓	
		Total	**7**

Question 2		
(a)	light waves diffract on passing through slits ✓ narrow slits (or $d \approx \lambda$) give wide diffraction ✓ diffracted waves meet or overlap or interfere ✓ maxima when waves are in phase or when path difference is $n\,\lambda$ ✓	**max 3**
(b) (i)	$n_1\,\lambda_1 = n_2\,\lambda_2$ (or $3 \times 420 = 2\,\lambda$) ✓ (gives $\lambda = 630\,\text{nm}$)	**5**
(ii)	$d\left(=\dfrac{n\lambda}{\sin\theta}\right)=\dfrac{3\times420\times10^{-9}}{\sin 44^\circ}$ $(=1.81\times10^{-6}\,\text{m})$ ✓ no of lines m^{-1} = $1/1.81\times10^{-6} = 5.5\times10^{5}$ (5.51×10^{5}) ✓	
(iii)	when $\sin\theta=1$, $n\left(=\dfrac{d}{\lambda}\right)=\dfrac{1.81\times10^{-6}}{420\times10^{-9}}$ $(=4.31)$ ✓ $\therefore$ highest order maximum is 4th ✓	
	Total	**8**

Jun 05 P4

Question 1		
(a)	reference to resonance ✓ air set into vibration at frequency of loudspeaker ✓ resonance when driving frequency = natural frequency of air column ✓ more than one mode of vibration ✓ stationary wave (in air column) ✓ (or reference to nodes and antinodes) maximum amplitude vibration (or max energy transfer) at resonance ✓ [alternative answer to (a): first two marks as above, remaining four marks for wave reflected from surface (of water) ✓ interference/superposition (between transmitted and reflected waves) ✓ maximum intensity when path difference is $n\lambda$ ✓ maxima (or minima) observed when l changes by $\lambda/2$ ✓]	**Max 4**
(b) (i)	$\dfrac{\lambda}{2}=523-168$ ✓ (= 355 mm) $\lambda = 710$ mm ✓ [if $\dfrac{\lambda}{4}=168$, giving λ = 670 mm, ✓ (1 max) (672 mm)]	**4**
(ii)	$c(=f\lambda) = 480\times0.71$ ✓ = 341 m s^{-1} ✓ (allow C.E. for incorrect λ from (i)) [allow $480\times0.67 = 320$ m s^{-1} ✓ (1max) (322 m s^{-1})]	

Jan 03 P3

1

(a) first pair in parallel $\frac{1}{R'} = \frac{1}{30} + \frac{1}{60}$ ✓

$= \frac{3}{60}$ gives $R' = 20$ (Ω) ✓

second pair in parallel $\frac{1}{R''} = \frac{1}{40} + \frac{1}{120}$ gives $R'' = 30$ (Ω) ✓

resistance between A and B = 20 + 30 ✓ (= 50 Ω)

(allow C.E. for values of R' and R'') (*4*)

(b)(i) total resistance = 50 + 50 = 100 Ω ✓

($V = IR$ gives) 24 = I 100 and I = 0.24 A ✓

(b)(ii) current in 60 Ω = $^{1}/_{3}\ I$ ✓

= 0.080 (A) ✓

[or alternative method]

(allow C.E. for value of I from (b)(i)) (*4*)

(*8*)

2

(a)(i) total resistance = 180 + 60 = 240 (Ω) ✓

($V = IR$ gives) 12 = I 240 and I = 0.05 A ✓

(a)(ii) very large or infinite resistance ✓

(a)(iii) $V = 0.05 \times 60 = 3.0$ V ✓

[or statement that $V = {}^{1}/_{4}$ of 12 V]

[or use of potentiometer equation

$$V_{\text{out}} = V_{\text{in}}\left[\frac{R_2}{R_1 + R_2}\right] = 12 \times \left[\frac{60}{240}\right] = 3.0\text{ V}]$$

(allow C.E. for value of I from (a)(i)) (*4*)

(b) parallel resistance gives lower equivalent resistance

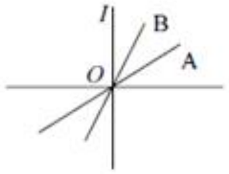
[or resistance of lower section of potentiometer reduced] ✓

total resistance in circuit reduced ✓

current through battery increases since V constant ✓ $_{\text{max}}$(*2*)

(*6*)

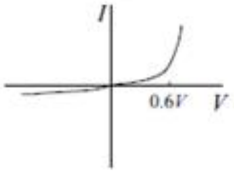
5(a)



straight line in both quadrants,
through origin for A and B ✓
greater gradient for B ✓

(2)

(b)



characteristic to show:
positive current increasing slowly and then rapidly ✓
at ≈ 0.6 V ✓
negative current either zero or just < zero ✓

(3)

(c) as voltage increases, current increases ✓
current heats filament ✓
therefore resistance increases ✓
correct argument to explain curvature ✓
mirror image in negative quadrant ✓

max(4)
(9)

Jan 04 P3

1

(a)(i) 5 V ✓

(ii) $R_T = 36\ (\Omega)$ ✓
(use of $V = IR$ gives) $15 = I \times 36$ and $I = 0.42$ A ✓ (3)

(b)(i) equivalent resistance of the two lamps $\frac{1}{R} = \frac{1}{12} + \frac{1}{12} = \frac{1}{6}$ ✓
$R_T = 6 + 12 = 18\ (\Omega)$ and $15 = I \times 18$ ✓ (to give $I = 0.83$ A)

(ii) current divides equally between lamps (to give $I = 0.42$ A)
(or equivalent statement) ✓ (3)

(c) same brightness ✓
(because) same current ✓ (2)
(8)

2

(a) constantan (wire) ✓
$I \propto V$
[or straight line through origin]
[or constant gradient]
[or V and I increasing proportionally]✓ (2)

(b)(i) (for $V = 1$ V, use of $V = IR$ gives) $R = \frac{1}{0.68 \pm .01} = 1.5\ \Omega$ ✓ $(1.47 \pm 0.02\ \Omega)$

(for $V = 10$ V) $R = \frac{10}{2.24 \pm .01} = 4.4$ or $4.5\ (\Omega)$ ✓ $(4.46 \pm 0.02\ (\Omega))$

(ii) as current increases ✓
greater heating effect (or temperature of filament increases) ✓
R increases with temperature ✓ max(4)

(c) $\rho = \frac{RA}{l}$ ✓

(R = 1/gradient, or use of values gives) $R = \frac{12}{2.2} = 5.5\ (\Omega)$ ✓ (5.45 (Ω))

$\rho = \frac{5.45 \times 6.8 \times 10^{-8}}{0.8} = 4.6 \times 10^{-7}\ \Omega\,\text{m}$ ✓ $(4.63 \times 10^{-7}\ \Omega\,\text{m})$

(allow C.E. for value of R *(3)*

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Question 1

(a)(i) (total) resistance = (20 + 60) (**Ω**) ✓

($V = IR$ gives) $I = \frac{6.0}{80} = 0.075$ A ✓

(ii) with S closed, (effective) resistance = 20 (Ω) ✓

$I = \frac{6.0}{20} = 0.3$ A ✓ max*(3)*

(b) use of same current as in part (i) ✓

voltmeter reading = 0.075 × 60 = 4.5 V ✓

[or use potentiometer equation $6 \times \frac{60}{80} = 4.5$ V] <u>(2)</u>

(allow C.E. for value of I from (a)(i) <u>(5)</u>

Question 2

(a)(i) circuit details:

diode (correct symbol) connected in correct direction,

plus ammeter in series with diode ✓

variable battery, variable resistor or potentiometer ✓

voltmeter across diode ✓

ammeter and voltmeter connected to data logger ✓

(ii) description: current and voltage recorded on data logger ✓

change voltage/current in (small) steps by changing

variable resistor/potentiometer/battery ✓

(iii) reverse the diode or battery ✓ max*(6)*

(b) correct characteristic in positive and negative quadrant ✓✓

current heats the filament

[or discussion of collisions with molecules] ✓

hence resistance increases ✓

rate of increase in I decreases [or suitable explanation] ✓

same **effect** when current reversed ✓ max<u>*(5)*</u>

<u>*(11)*</u>

Question 3

(a) at 200 °C: $R_R = 130 \pm 1$ (Ω), $R_{Th} = 18 \pm 1$ Ω ✓ *(1)*

(b)(i) $V_{AB} = V_{in}\dfrac{R_{Th}}{R_{Th}+R_R}$ ✓

$= 12 \times \dfrac{18}{18+130}$ ✓

$= 1.5$ V ✓ (1.46 V)

(allow C.E. for values from (a))

(ii) $R_{th} = R_R$ occurs at 50 °C ✓ *(4)*

(c)(i) (use of $P = \dfrac{V^2}{R}$ gives) $R_b = \dfrac{36}{2} = 18\,\Omega$ ✓

[or use of $P = VI$ and calculate I]

(ii) (S open, $R_{Th} \approx 90\,\Omega$)

bulb and thermistor in parallel ✓

gives lower resistance than thermistor on its own ✓

total resistance in circuit decreases ✓

current increases ∴ $V_R > 6$ V ✓

(hence $V_{th} < 6$ V i.e. decreases)

[or use of potentiometer equation, or ratio of resistances and share of pd] max*(4)*

(9)

Question 4

(a) $R = \dfrac{\rho l}{A}$ ✓

ρ is resistivity, l is the length of the wire, A is the cross-sectional area ✓ *(2)*

(b)(i) $P = \dfrac{V^2}{R}$ ✓

$R = \dfrac{230^2}{500} = 106(\Omega)$ ✓ (105.8 Ω)

$l = \left(\dfrac{RA}{\rho}\right) = \dfrac{105.8 \times 8.0 \times 10^{-8}}{1.1 \times 10^{-6}} = 7.7$ m ✓ (7.69 m)

(allow C.E. for incorrect value of R)

(ii) in series, voltage across each < 230 V or pd shared ✓

∴power (= V^2/R) is less than 500 W in each ✓

in parallel, voltage across each = 230 V ✓

∴correct rating, ∴conclusion ✓

[or, in series, high resistance or combined resistance ✓

∴low current ✓

in parallel, resistance is lower, ∴higher current ✓

more power, justified ✓] max*(6)*

(8)

Question 5

(a) ($V = IR$ gives) $V_{rms} = (5.3 \times 10^{-3} \times 2 \times 10^{3}) = 10.6$ (V) ✓
$V_0 = V_{rms}\sqrt{2} = 10.6\sqrt{2} = 15$ V ✓ (14.99 V)
[or calculate I_0 (= 7.5 mA) and then V_0] *(2)*

(b) (use of $T = \frac{1}{f}$ gives) $T = \frac{1}{500} = 2 \times 10^{-3} = 2$ 0(ms) ✓
trace to show: correct wave shape (sinusoidal) ✓
correct amplitude (3 divisions) ✓
correct period (8 divisions) ✓ *(4)*

(6)

Jan 06 P3

Question 1		
(a)	$I = \frac{\Delta Q}{\Delta t}\left(\text{or } I = \frac{Q}{t}\right)$ ✓ $\Delta Q = 0.25 \times 6 \times 60 = 90$ C ✓	**2**
(b) (i) (ii)	$V = \frac{W}{Q}$ ✓ [or $E = VIt$] $= \frac{9.0 \times 10^4}{0.25 \times 20 \times 60 \times 60} = 5.0$ V ✓ (use of $P = \frac{W}{t}$ gives) $P = \frac{9.0 \times 10^4}{20 \times 60 \times 60} = 1.2(5)$ W ✓ [or $P = IV$ gives $P = 0.25 \times 5 = 1.2(5)$ W] (allow C.E. in alternative method for value of V from (i))	**3**
	Total	**5**

Question 2		
(a) (i) (ii)	(use of $V = IR$ gives) $12 = I \times 270$ and $I = 44.(4)$ mA ✓ two resistors in parallel give resistance less than 110 Ω ✓ (∴) total resistance decreases ✓ current increases ✓	**4**
(b)	$V = 44.4 \times 10^{-3} \times 110$ ✓ (= 4.9 V) [or $V = 12 \times \left(\frac{110}{110 + 160}\right)$] (assumption) no current flows through voltmeter ✓ [or voltmeter has very large or infinite resistance]	**2**
(c)	total resistance (in circuit) = 160 (Ω) ✓ $12 = I \times 160$ and $I = 75$ mA ✓	**2**
	Total	**8**

Question 3		
(a) (i)	circuit diagram to show: wire, ammeter, battery, (variable resistor) and switch in series ✓ [or potentiometer with ammeter in correct position] voltmeter across the wire ✓	
(ii)	(method: constant length of wire) measure length (of wire) ✓ measure diameter (of wire) ✓ measure voltage (across) and current (through wire) ✓ vary resistor to obtain different voltage and current ✓ **alternative** [(method: variable length of wire) measure length (each time) ✓ measure diameter ✓ (for full length of wire) measure voltage and current ✓ voltmeter to shorter lengths, measure voltage (and current) ✓]	
(iii)	(use of) $\rho = \frac{RA}{l}$ (to calculate ρ) ✓ (for either method) calculate A from (πr^2) ✓ (for either method) (method: constant length of wire) determine $R\left(=\frac{V}{I}\right)$ for (one) length ✓ repeat readings (for same length and) take mean of ρ or R ✓ [or plot graph of V vs I to give mean R ✓ or gradient $=\frac{\rho l}{A}$ ✓] **alternative** [(method: variable length of wire) determine $R\left(=\frac{V}{I}\right)$ for each length ✓ calculate ρ for each length and take mean ✓ [or graph of R vs l ✓ with correct gradient ✓]	**10**
(b)	(use of $R=\frac{\rho l}{A}$ gives) $\frac{2.0}{4.0}=\frac{1.1\times10^{-7}l}{7.8\times10^{-9}}$ ✓ $l = 0.035$ m ✓	**2**
	Total	**12**

Question 4		
(a) (i)	electrical energy produced (in the battery) per unit charge ✓ [or potential/voltage across terminals when there is no current]	**Max 2**
(ii)	there is a current (through the battery) ✓ voltage 'lost' across the internal resistance ✓	
(b) (i)	$\in = V + Ir$ ✓	**8**
(ii)	labelled scales ✓ correct plotting ✓ best straight line ✓ $\in$: intercept on y axis ✓ = 9.2 (± 0.1) V ✓ r : (−) gradient ✓ $= \dfrac{9.2}{0.65} = 14.2\ \Omega$ ✓ (range 14.0 to 14.3)	
	Total	**10**

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Question 2		
(a)	(use of potentiometer equation $V_2 = \dfrac{R_2}{R_1 + R_2} V$ gives) $V_2 = \dfrac{120}{80 + 120} \times 12$ ✓ $= 7.2\,\text{V}$ ✓ [or calculate current = 60 mA (✓), and hence V_2 (✓)] (assumption): no current through the voltmeter or voltmeter has infinite/very high resistance ✓	**3**
(b)	resistance of **parallel** section decreases ✓ **total** resistance/resistance of circuit decreases ✓ emf/voltage is constant, ∴ I increases ✓	**3**
	Total	**6**

Question 3		
(a) (i)	measure I and V ✓ measure l ✓ repeat measurements at different l ✓	**7**
(ii)	use of $\rho = \dfrac{AR}{l}$ or $\rho = \dfrac{A}{l}\dfrac{V}{I}$ to require ✓ graph of R vs l with $R = \dfrac{V}{I}$, or V vs l ✓ statement: (straight) line and measure gradient ✓ gradient of graph = $\dfrac{\rho}{A}$ or $\dfrac{\rho I}{A}$ (with I constant) hence ρ ✓	
(b)	$R = \dfrac{210}{1.4 \times 10^{-3}}$ $(= 1.5 \times 10^{5}\,(\Omega))$ ✓ $\rho = \left(\dfrac{RA}{l}\right) = \dfrac{1.5 \times 10^{5} \times 90 \times 90 \times 10^{-6}}{1.1 \times 10^{-3}}$ ✓ $= 1.1 \times 10^{6}\,\Omega\,\text{m}$ ✓	**3**
	Total	**10**

Jun 03 P3

1

(a) between A and C: (each) series resistance = 100 Ω ✓

(parallel resistors give) $\frac{1}{100}+\frac{1}{100}=\frac{1}{50}$ gives $R_{AC} = 50\ \Omega$ ✓ *(2)*

(allow C.E. for incorrect series resistance)

(b) between A and B: series resistance = 150 Ω ✓

parallel = $\frac{1}{50}+\frac{1}{150}$ ✓

(allow C.E. for series resistance)

$R_{AB} = 37.5\ \Omega$ ✓ (38 Ω) *(3)*

(5)

3

(a)(i) for X: ($P = VI$ gives) $24 = 12I$ and $I = 2$ A ✓
for Y $18 = 6I$ and $I = 3$ A ✓ *(2)*

(b)(i) 12 V ✓

(b)(ii) voltage across R_2 (= 12 – 6) = 6 (V) ✓
$I = 3$ (A) ✓
($V = IR$ gives) $6 = 3R_2$ and $R_2 = 2\ \Omega$ ✓
(allow C.E. for I and V from (a) and (b)(i))

[or $V = I(R_y + R_2)$ ✓ $12 = 3(2 + R_2)$ ✓ $R_2 = 2\ \Omega$ ✓]

(b)(iii) current = 2 (A) + 3 (A) = 5 A ✓

(allow C.E. for values of the currents)

(b)(iv) 27 (V)– 12 (V) = 15 V across R_1 ✓

(b)(v) for R_1, $15 = 5\ R_1$ and $R_1 = 3\ \Omega$ ✓

(allow C.E. for values of I and V from (iii) and (iv)) <u>(7)</u>

<u>(9)</u>

4

(a)(i) battery, milliammeter, and wire in series ✓ ✓

voltmeter across the wire ✓

variable resistor/potential divider in series ✓

(a)(ii) alter variable resistor ✓

to obtain a series of values of I and V ✓

(a)(iii) plot a graph of V against I ✓

gradient = R ✓

[or calculate $R = V/I$ for <u>each reading</u> and take mean] (8)

(b)(i) ($P = \frac{V^2}{R}$ gives) $1200 = \frac{230^2}{R}$ ✓

$R = 44.1\ \Omega$ ✓

(b)(ii) $R = \frac{\rho l}{A}$ ✓

$$l = \frac{44.1 \times 9.4 \times 10^{-8}}{1.1 \times 10^{-6}}$$ ✓

= 3.8 m ✓

(allow C.E. for value of R in (i)) <u>(5)</u>

<u>(13)</u>

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2

(a)(i) $\frac{1}{R} = \frac{1}{40} + \frac{1}{40} + \frac{1}{40}$ ✓

$R = \frac{40}{3} = 13\ (\Omega)$ ✓ (13.3)

(ii) two resistors in parallel give 20 (Ω) ✓

$R = 20 + 40 = 60\ (\Omega)$ ✓ max (3)

(b)(i) three resistors in parallel give $\frac{1}{6}+\frac{1}{6}+\frac{1}{6}$ (= 2 (Ω)) and total resistance = 4 (Ω) ✓

total current = $\frac{12}{4}$ = 3 (A) ✓
(allow C.E. for value of total resistance)
current in each element 1.0 A ✓
(allow C.E. for value of total current)

[or 6 V across each set
resistance of each set = 2 Ω, gives current through each set = 3 (A)
current in each element = 1.0 A]
[or 6 V across each set/resistor,
resistance of one resistor = 6 Ω, gives current in each element = 1.0 A]

(ii) six resistors in series gives R = 36 (Ω) and $I = \frac{12}{36}$ = 0.3 (A) ✓
heating effect (I^2R) much reduced [or less power] ✓ *(5)*
(8)

3

(a) $V = -Ir + \epsilon$ ✓ *(1)*

(b) straight line (within 1st quadrant) ✓
negative gradient ✓ *(2)*

(c) ϵ: intercept on voltage axis ✓
r: gradient ✓ *(2)*
(5)

4

(a) $\rho = \frac{RA}{l}$ ✓
R = resistance (of wire), A = **cross-sectional** area, l = length (of wire) ✓ *(2)*

(b)(i) $R = \frac{\rho l}{A} = \frac{4.0\times10^{-5}\times30\times10^{-3}}{8\times10^{-3}\times2\times10^{-6}}$ ✓
= 75 Ω ✓

(ii) length has decreased causing resistance to decrease ✓
area increased, causing resistance to decrease ✓
each changed by factor of 1.5×10^3 ✓ *(4)*
(6)

5

(a)(i) at 25 (°C), total resistance = 300 + 200 = 500 (Ω) ✓

$$I = \frac{12}{500} = 24\,\text{mA}$$ ✓

(allow C.E. for value of total resistance)

(ii) pd across thermistor = $24 \times 10^{-3} \times 300 = 7.2$ V ✓

(allow C.E. for value of current from (i) and R_{th} from graph) *(3)*

(b) as temperature increases, resistance (of thermistor) decreases ✓
total resistance decreases ✓
current in circuit increases ✓
pd across resistor increases ✓
(since battery remains at 12 V) pd across thermistor decreases ✓

[or R_{th} decreases ✓
potential divider situation ✓

$$V_{th} = 12 \times \frac{R_{th}}{(R_{th} + R)}$$ ✓

denominator decrease less slowly than numerator ✓
V_{th} decreases ✓
or for last two marks, thermistor gets smaller share of voltage
explanation of this] $_{\text{max}}$ *(3)*

(c)(i) (use of $P = \frac{V^2}{R}$ gives) at 25 °C $P = \frac{144}{300} = 0.48$ W ✓

at 45 °C correct reading of R = 30 (Ω)✓

$$P = \frac{144}{30} = 4.8\ (\text{W})$$ ✓

(ii) $E = Pt = 2.64 \times 10 \times 60$ ✓
$= 1.6 \times 10^3$ J ✓
(allow C.E. from part (i))

(iii) rate of decrease of resistance is not linear
[or resistance not directly proportional to temperature] ✓ *(6)*

(12)

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Question 1		
(a) (i)	no of bulbs = $\left(\frac{230}{5}\right) = 46$ ✓	5
(ii)	(use of $P = VI$ gives) $I = \left(\frac{0.4}{5}\right) = 0.080$ A ✓	
(iii)	resistance of each bulb $= \frac{230}{0.080 \times 46} = 63\ \Omega$ ✓ $(62.5\ \Omega)$ (allow C.E. for number of bulbs and value of I) [or $R\left(=\frac{V}{I}\right) = \frac{5}{0.08} = 62.5\ \Omega$ or $\left(P = \frac{V^2}{R} \text{ gives}\right) R = \frac{25}{0.40} = 62.5\ \Omega$]	
(iv)	energy consumed by the set $= 0.4 \times 46 \times (2 \times 60 \times 60)$ ✓ $= 132$ kJ ✓ (allow C.E. for number of bulbs from (i))	
(b) (i)	no of bulbs = 56, gives total resistance $= 62.5 \times 56\ (\Omega)\ (= 3500)$ ✓ $I = \frac{230}{3500} = 0.066$ A ✓ (0.0657 A) (use of 63 Ω gives 0.065 A) (allow C.E. for no. of bulbs in (a) (i) and R in (a) (iii))	3
(ii)	bulbs would shine less bright ✓	

Question 3		
(a)	**battery** has internal resistance ✓ **current** passes through (this resistance) ✓ work done/voltage lost, which reduces the value of the emf ✓	3
(b) (i)	circuit diagram to show: two **cells** in series ✓ two resistors, each labelled r ✓	5
(ii)	(use of $P = IV$ gives) $1.6 = 2.5\,I$ ✓ $(I = 0.64$ (A)) (use of $\epsilon = V + Ir$ gives) $3.0 = 2.5 + 0.64 \times 2r$ ✓✓ $0.5 = 1.28r$ and $r = 0.39\ \Omega$ ✓ [or $R_{\text{bulb}} = 2.5^2/1.6 = 3.9\ (\Omega)$ and $2.5 = 3.9 \times I$ gives $I = 0.64$ (A) 'lost volts' $= (3 - 2.5) = 0.5$ (V) i.e. 0.25 (V) per cell $0.25 = 0.64r$ and $r = 0.39\ \Omega$]	
(c)	$\epsilon = V + Ir$ gives $V = -Ir + \epsilon$ (equation of straight line) ✓ intercept on y-axis gives ϵ ✓ gradient gives $(-)r$ ✓	3

Question 4		
(a)	circuit diagram to show: (milli)ammeter in series with thermistor, which must have correct symbol ✓ voltmeter across thermistor ✓ variable resistor/variable power supply/potentiometer in series with thermistor ✓ variable component labelled ✓	**4**
(b) (i)	resistance (when $I = 0.1$ mA) = (44±0.1(ma)/0.1) = 44±1 × 10^3 (Ω) ✓ resistance (when $I = 0.6$ mA) = (17/0.6) = 28 × 10^3 Ω ✓	**5**
(ii)	resistance decreases with increasing current ✓ (from (b) (i)) as current increases thermistor heats up ✓ ∴ resistance decreases as temperature increases ✓	

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Question 3		
(a) (i)	battery has internal resistance ✓ part of emf is the voltage across internal resistance ✓	**4**
(ii)	(use of $P = IV$ gives) $I = \frac{1.6}{3.8}$ = 0.42 (A) ✓ (use of $\in = V + Ir$ gives) 4.0 – 3.8 = 0.42 r and r = 0.48 Ω ✓ [or $\in = I(R + r)$, with $R = 9.0(3)$ Ω]	
(b)	measure I and V (for given R) ✓ change R and repeat readings ✓ draw graph of V vs I ✓ correct sketch graph [V(y) vs I(x)] showing negative gradient ✓ ($\in = V + Ir$ gives) y-intercept = $\in$ ✓ gradient = (–)r ✓ [accept I(y) vs V(x), gradient = (–)1/r , intercept on y axis = $\in / r$]	**max 5**
	Total	**9**

Question 4		
(a)	(resistance of element given by $\frac{1}{R}=\frac{1}{12}+\frac{1}{12}$) R = 6.0 (Ω) ✓ $P\left(=\frac{V^2}{R}\right)=\frac{144}{6}$ ✓ (= 24 W)	**2**
(b)	in parallel, 12 V across each element ✓ heat generated = (2 × 24) = 48 (W) ✓ [or alternative method] in series, 6 V across each element ✓ heat generated = (2 × (36/6)) = 12 (W) ✓	**4**
(c)	$R=\frac{\rho l}{A}$ ✓ $l=\frac{12\times2.5\times1.2\times10^{-6}}{4.3\times10^{-5}}$ = 0.83(7) m ✓	**2**
	Total	**8**

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1

(a) 6 (protons) and 6 (electrons) ✓
8 (neutrons) ✓ *(2)*

(b)(i) $(2\times1.6\times10^{-19})=3.2\times10^{-19}$ (C) ✓

(b)(ii) 14 ✓

(b)(iii) $m=14\times1.67\times10^{-27}$ (kg) ✓

$$\frac{Q}{m}=\left(\frac{3.2\times10^{-19}}{14\times1.67\times10^{-27}}\right)=1.4\times10^{7}\ (\text{C kg}^{-1})\ ✓\quad(1.37\times10^{7}\ (\text{C kg}^{-1}))$$

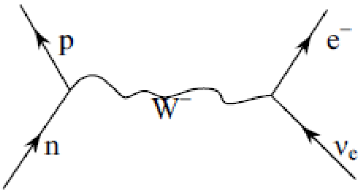
(allow C.E for values from (i) and (ii)) *(4)*

(6)

4

(a)(i) weak interaction ✓

(a)(ii)



e^- ✓
p ✓

(3)

(b)(i) obeyed: baryon number
lepton number
charge
any two ✓ ✓
not obeyed: strangeness ✓

(b)(ii) $K^o = \bar{s}\,d$ ✓
$\pi^+ = u\,\bar{d}$ ✓
$\pi^- = \bar{u}\,d$ ✓

<u>(6)</u>
<u>(9)</u>

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2

(a) baryon qqq
antibaryon $\overline{qqq}$
meson $q\bar{q}$

two names ✓
composition of each sub-group ✓✓ (3)

(b)(i) $n \rightarrow p$ ✓ + ${}^{0}_{-1}\beta^-$ ✓ + $\bar{\nu}_{(e)}$ ✓

(ii) a down (d) quark changes to an up (u) quark
[or udd changes to uud] ✓

<u>(4)</u>
<u>(7)</u>

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Question 4

(a) baryon number
lepton number
charge
strangeness (any three) ✓✓✓ *(3)*

(b)

Feynman diagram to show:
p changing to n ✓
W^+ ✓
β^+ and ν_e ✓
correct overall shape with arrows ✓ *(4)*

(c)

particle	fundamental particle	meson	baryon	lepton
p		×	✓	×
n		×	✓	×
β^+	✓	×	×	✓
ν_e	✓	×	×	✓

✓✓✓✓ (one for each correct line) *(4)*

(11)

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Question 1		
(a)	$^{12}_{6}\text{C}$ ✓	**1**
(b)	2e ✓ $= (2 \times 1.6 \times 10^{-19}) = 3.2 \times 10^{-19}\,\text{C}$ ✓	**2**
(c)	$\left(\frac{Q}{m}\right) = \frac{6 \times 1.6 \times 10^{-19}}{14 \times 1.67 \times 10^{-27}}$ ✓ $= 4.1(1) \times 10^{7}\,\text{C kg}^{-1}$ ✓	**2**
	Total	**5**

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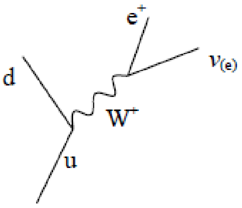
Question 1		
(a)	(a=21; b=10) protons = 10 ✓ neutrons = 11 ✓	**2**
(b)	nuclides with the same number of protons ✓ but different number of neutrons ✓ (alternatives allowed)	**2**
(c)	charge = $2 \times 1.6 \times 10^{-19}$ (C) ✓ mass = $3 \times 1.67 \times 10^{-27}$ (kg) ✓ charge/mass = $6.4 \times 10^{7}\,\text{C kg}^{-1}$ ✓	**3**
	Total	**7**

Question 3		
(a) (i)	baryon number ✓ lepton number ✓	**3**
(ii)	$p \rightarrow n + e^+ + \nu_{(e)}$ ✓	
(b)	 u and d ✓ W^+ ✓ (with arrow or correct slope) e^+ and $\nu_{(e)}$ ✓	**3**
	Total	**6**

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1

(a)(i) (charge) = $92 \times 1.60 \times 10^{-19}$ ✓
$= 1.47 \times 10^{-17}$ (C) ✓

(ii) (magnitude of ion charge) = 3(*e*) ✓
number of electrons (= 92 – 3) = 89 ✓ *(4)*

(b) X: number of nucleons [or number of neutrons plus protons or mass number] ✓
239 ✓
Y: number of protons [or atomic number] ✓
94 ✓ *(4)*
(8)

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Question 1		
(a)	(atoms with) same number of protons/same atomic number ✓ different number of neutrons/mass number/ nucleons ✓	**2**
(b) (i)	7 protons ✓ 8 neutrons ✓	**4**
(ii)	$\left(\frac{\text{charge}}{\text{mass}}\right) = \frac{7\times1.6\times10^{-19}}{15\times1.67\times10^{-27}}$ ✓ $= 4.5 \times 10^{7}$ (C kg^{-1}) ✓ (4.47×10^{7} (C kg^{-1})) (allow C.E. for incorrect values in (b) (i))	
(c) (i)	(+) 1.6×10^{-19} (C) ✓	**2**
(ii)	positive ion ✓	

Question 6			
(a)	(i)	$\bar{\nu}_e + p \rightarrow n$ ✓ $+ e^+$ ✓	**4**
	(ii)	weak ✓	
	(iii)	W^+ or W^- ✓	
(b)		γ photon or high energy photon/kinetic energy ✓ converted to a particle and its antiparticle ✓ $p + \bar{p}$ or $e^- + e^+$ ✓	**3**

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Question 2			
(a)		pair production ✓	**1**
(b)	(i)	the γ ray must provide enough energy to provide for the (rest) mass ✓ any extra energy will provide the particle(s) with **kinetic** energy ✓	**3**
	(ii)	$(0.511 + 0.511) = 1.022$ (MeV) ✓	
(c)		any pairing of a particle with its corresponding antiparticle (e.g. $p + \bar{p}$) ✓	**1**
		Total	**5**

Question 6			
(a)		n ✓ $+ \nu_{(e)}$ ✓ μ^- ✓ K^+ ✓	**4**
(b)		$d \rightarrow u + \beta^- + \bar{\nu}_{(e)}$ ✓✓	**2**
(c)	(i)	weak interaction ✓	**3**
	(ii)	lepton ✓	
	(iii)	electromagnetic and gravitational ✓	
		Total	**9**

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Question 1		
(a)	neutrons (= 55 – 26) = 29 ✓ electrons = 26 protons = 26 ✓	**2**
(b)	charge = $26 \times 1.6 \times 10^{-19}$ ✓ mass = $55 \times 1.67 \times 10^{-27}$ ✓ charge/mass = 4.5×10^{7} C kg^{-1} ✓	**3**
(c)	a = 55 ✓ b = 27 ✓	**2**
	Total	**7**

Question 2		
(a)	qqq (or $\overline{qqq}$) ✓	**1**
(b)	meson ✓ $q\overline{q}$ ✓	**2**
(c)	neutral pion or π^{o} ✓	**1**
(d)	proton ✓	**1**
(e)	as strangeness is not conserved ✓ **or** weak link interaction is the only interaction that changes the type of quark ✓	**1**
	Total	**6**

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5

(a)(i) electrons fall down from orbits or energy levels and emit light/photons ✓
emitted wavelengths/frequencies/photon energies are discrete ✓
[or the transitions are between definite/fixed (energy)levels ✓

(a)(ii) C → B ✓

(a)(iii) between D → C and C → A ✓
the two arrows must point down ✓ $_{\text{max}}$*(4)*

(b)(i) (use of $hf = E_2 - E_1$ gives)

$$f = \left(\frac{2.3 \times 10^{-19}}{6.6 \times 10^{-34}}\right) = 3.5 \times 10^{14} \text{ Hz} \checkmark$$

$f = 3.2 \times 10^{14}$ (Hz) ✓
$f = 0.3 \times 10^{14}$ (Hz) ✓

(ii) 4.6×10^{-19} (J) ✓

$$\left(= \frac{4.6 \times 10^{-19}}{1.6 \times 10^{-19}}\right) = 2.9 \text{ (eV)} \checkmark$$ *(5)*

(9)

6

(a)(i) the minimum energy ✓
energy required to eject a (photo)electron (from the metal surface) ✓

(a)(ii) changing the metal/cathode ✓ *(3)*

(b) conclusion : light below a threshold frequency does not release electrons ✓
explanation: photons carry quanta of energy ✓

[or conclusion: electrons are emitted immediately the light hits the metal surface ✓
explanation : photons carry quanta of energy ✓] *(2)*

(c)(i) (use of $E = hf = \frac{hc}{\lambda}$ gives) $E = \frac{6.63\times10^{-34} \times 3\times10^{8}}{4.80\times10^{-7}}$ ✓ $= 4.14 \times 10^{-19}$ (J) ✓

(c)(ii) $hf = \phi + E_k$ ✓
$E_k = 4.14 \times 10^{-19} - 1.20 \times 10^{-19}$ ✓
$= 2.94 \times 10^{-19}$ (J) ✓
(allow C.E for value of E from (i)) *(5)*
(10)

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6

electrons diffract [or high energy electron scattering]✓
showing wave behaviour ✓

electrons are deflected in electric or magnetic fields ✓
showing particle behaviour ✓

interference of electromagnetic waves ✓
showing wave behaviour ✓

photoelectric effect ✓
showing particle behaviour ✓ max*(6)*
(6)

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Question 2

(a)(i) k.e. = $\frac{4.1\times10^{-18}}{1.6\times10^{-19}}$ ✓
= 26 (eV) ✓ (25.6 eV)

(ii) (use of $\lambda_{dB} = \frac{h}{mv}$ gives) $\lambda_{dB} = \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times3.0\times10^{6}}$ ✓
$= 2.4 \times 10^{-10}$ m ✓ (2.42×10^{-10} m) *(4)*

(b) (use of $hf = E_1 - E_2$ gives) $f = \frac{(0.90-0.21)\times10^{-18}}{6.6\times10^{-34}}$ ✓ (= 1.05×10^{15} (Hz))

(use of $\lambda = \frac{c}{f}$ gives) $\lambda = \frac{3.0\times10^{8}}{1.05\times10^{15}}$ ✓
$= 2.9 \times 10^{-7}$ m ✓ (2.86×10^{-7} m) *(3)*
(7)

Question 5

(a) (E_k =) maximum ✓
kinetic energy of the (emitted) (photo) electrons ✓ *(2)*

(b)(i) (use of $f = \frac{c}{\lambda}$ gives) $f = \frac{3 \times 10^8}{190 \times 10^{-9}}$ = 1.6×10^{15} Hz ✓ (1.58×10^{15} Hz)

(ii) energy of incident photon (= hf) = $6.6 \times 10^{-34} \times 1.6 \times 10^{15}$ or 1.1×10^{-18} (J) ✓
(allow C.E. for value of f from (i))
(use of $f = 1.58 \times 10^{15}$ gives energy = 1.04×10^{-18} (J))
incident energy is greater than the work function ✓

[or threshold frequency (= $\frac{\phi}{h}$) = $\frac{7.9 \times 10^{-19}}{6.6 \times 10^{-34}}$ = 1.2×10^{15} (Hz) ✓
(incident) frequency is greater than the threshold frequency ✓]

(iii) number of photons per sec is doubled
(maximum) photon/electron (kinetic) energy is constant
number (of photoelectrons) emitted (per second) is increased (or doubled)
one photon collision with one electron (any three) ✓✓✓ *(6)*

(8)

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Question 6		
(a) (i) (ii)	when an atom loses an orbiting electron (and becomes charged) ✓ $\frac{4.11 \times 10^{-17}}{1.6 \times 10^{-19}}$ = 260 (eV) ✓ (257 (eV))	2
(b) (i) (ii)	the electron in the ground state leaves the atom ✓ with remaining energy as kinetic energy (0.89×10^{-17} J) ✓ the orbiting electrons fall down ✓ to fill the vacancy in the lower levels ✓ various routes down are possible ✓ photons emitted ✓ taking away energy ✓	**Max 4**
(c)	E to D **and** D to B ✓ both in correct order ✓	2
	Total	8

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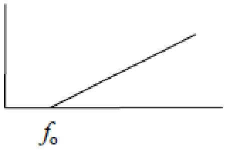
Question 4		
(a) (i)	minimum frequency ✓ of electromagnetic radiation required to eject photoelectrons from a metal surface ✓	**4**
(ii)	 straight line with positive gradient ✓ intercept on frequency axis with f_o labelled ✓	
(b) (i)	use of $\phi = hf_o$ ✓ f_o ($= 3.0 \times 10^{-19}/6.6 \times 10^{-34}$) $= 4.5 \times 10^{14}$ Hz ✓	**7**
(ii)	use of $E = hc / \lambda$ ✓ $= (6.6 \times 10^{-34} \times 3.0 \times 10^{8}/3.0 \times 10^{-7}) = 6.6 \times 10^{-19}$ (J) ✓ use of $hf = \phi + E_k$ ✓ $E_k = (6.6 \times 10^{-19} - 3.0 \times 10^{-19}) = 3.6 \times 10^{-19}$ J ✓	
(iii)	mercury and tungsten ✓	
	Total	**11**

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6

(a)(i) an electron moves <u>up</u> from one energy level to another ✓

(a)(ii) an electron is removed from an atom ✓ (2)

(b) (use of $hf = E_2 - E_1$ gives) $f = (2.56 - 1.92) \times 10^{-19}$ ✓$/6.63 \times 10^{-34}$

$= 9.65 \times 10^{13}$ Hz ✓

(allow C.E. for incorrect ΔE) (2)

(4)

7

(a)(i) electrons behave as both particles and waves ✓

(a)(ii) particle: deflection in an electromagnetic field

or other suitable examples ✓

wave: electron diffraction ✓ (3)

(b) (use of $\lambda = \frac{h}{mv}$ gives) $$v\left(=\frac{h}{m\lambda}\right) = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.7 \times 10^{-10}}$$ ✓

$= 4.28 \times 10^{6}$ m s^{-1} ✓ (2)

(5)

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5

(a) electrons in energy levels/orbits ✓
excited to **higher** levels/orbits ✓
electrons relax/fall down and emit photons/em radiation ✓
photon energies/frequencies are discrete ✓
hence wavelengths are discrete ✓
intensity depends on number of photons per sec max *(4)*

(b) (ultraviolet) radiation (from mercury vapour) excites/absorbs ✓
the atoms of the powder in the tube ✓
these (atoms) de-excite and produce radiation ✓
radiation is visible light ✓ *(4)*

(8)

6

(a)(i) (use of $\lambda = \frac{h}{mv}$ gives) $v = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.2 \times 10^{-8}}$ ✓

$= 2.3 \times 10^4 \text{ m s}^{-1}$ ✓ $(2.27 \times 10^4 \text{ m s}^{-1})$

(ii) (use of λ inversely proportional to m when v is constant, gives)

$$\lambda_p \left(= \lambda_e \frac{m_e}{m_p} \right) = \frac{3.2 \times 10^{-8} \times 9.11 \times 10^{-31}}{1.67 \times 10^{-27}}$$ ✓

$= 1.7 \times 10^{-11} \text{ m}$ ✓

[or $\lambda \left(= \frac{h}{mv} \right) = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 2.27 \times 10^4}$

$= 1.7 \times 10^{-11} \text{ m}$ $(1.746 \times 10^{-11} \text{ m})$]

(allow C.E. for value of v from (a) (i)) *(4)*

(b)(i) diffraction (experiments) ✓

(ii) easier to obtain electrons (to accelerate)
[or easier to get λ same size as scattering object] ✓ *(2)*

(6)

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Question 2		
(a)	an electron is excited/promoted to a higher level/orbit ✓ reason for excitation: e.g. electron impact/light/energy externally applied ✓ electron relaxes/de-excited/falls back emitting a photon/em radiation ✓ wavelength depends on the energy change ✓	**Max 3**
(b) (i)	use of $E = hf$ gives) $E = \frac{hc}{\lambda}$ ✓ $= \frac{6.6\times10^{-34}\times3.0\times10^{8}}{4.0\times10^{-7}} = 5.0\times10^{-19}$ (J) ✓ (4.95×10^{-19} (J)) and $\left(\frac{6.6\times10^{-34}\times3.0\times10^{8}}{2.0\times10^{-7}}\right) = 9.9\times10^{-19}$ (J) ✓	**5**
(ii)	(energy of) level B = -1.5×10^{-18} (J) ✓ level C = (−) 1.0×10^{-18} (J) ✓	

Question 5		
(a)	minimum (energy/work done) ✓ energy required to remove an electron from the surface (of the metal) ✓	**2**
(b) (i)	$E_k = hf - \phi$ ✓	**6**
(ii)	$f_0 = 0.50\times10^{15}$ (Hz) ✓ $\phi\ (= hf_0) = 6.6\times10^{-34}\times0.50\times10^{15}$ ✓ $= 3.3\times10^{-19}$ J ✓	
(iii)	(use of $E_k = hf - \phi$ gives) $E_k = (6.6\times10^{-34}\times2.5\times10^{15}) - 3.3\times10^{-19}$ ✓ $= 1.3(2)\times10^{-18}$ J ✓ (allow C.E. for incorrect value of ϕ from (ii)) [or (using gradient = $h = \Delta E_k/\Delta f$) $\Delta E_k = 6.6\times10^{-34}\times2\times10^{15}$ ✓ $= 1.3(2)\times10^{-18}$ J ✓]	
(c)	same gradient ✓ drawn above existing line with smaller x intercept ✓	**2**

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Question 4		
(a)	intensity determines the number of photons per second ✓ fewer photoelectrons per second ✓ (individual) photon energies are not changed ✓ with no change in the (kinetic) energy/speed ✓ one photon interacts with one electron ✓	**max 3**
(b)	energy of a photon is proportional to frequency (or $E = hf$) ✓ photon of red light has less energy than a photon of blue light [or $f_{\text{red}} < f_{\text{blue}}$ or $\lambda_{\text{red}} > \lambda_{\text{blue}}$] ✓ the energy is insufficient to overcome the work function of the metal [or the frequency is below the threshold frequency] ✓	**3**
(c) (i)	$f\left(=\dfrac{3.0\times10^{8}}{200\times10^{-9}}\right) = 1.5\times10^{15}\,\text{Hz}$ ✓	**5**
(ii)	$f_0\left(=\dfrac{\phi}{h}\right)=\dfrac{2.3\times10^{-19}}{6.63\times10^{-34}}$ ✓ $= 3.5\times10^{14}\,\text{Hz}$ ✓ $(3.47\times10^{14}\,\text{Hz})$	
(iii)	(use of $hf = \phi + E_k$ gives) $E_k = (6.63\times10^{-34}\times1.5\times10^{15}) - 2.3\times10^{-19}$ ✓ $= 7.6\times10^{-19}$ (J) ✓ $(7.645\times10^{-19}$ (J)) (allow C.E. for value of f from (i))	
	Total	**11**

Question 5		
(a) (i)	$(3.40 - 1.51 = 1.89)$ $\Delta E = 1.89\times1.60\times10^{-19}$ (J) ✓ $(=3.02\times10^{-19}$ (J)) $f\left(=\dfrac{\Delta E}{h}\right)=\dfrac{3.02\times10^{-19}}{6.63\times10^{-34}}$ ✓ $(=4.56\times10^{14}\,\text{Hz})$	**3**
(ii)	$\lambda\left(=\dfrac{c}{f}=\dfrac{3.00\times10^{8}}{4.56\times10^{14}}\right)=6.5(8)\times10^{-7}\,\text{m}$ ✓ (use of $f = 4.6\times10^{14}$ gives $\lambda = 6.5\times10^{-7}$ m)	
(b) (i)	6 (wavelengths) ✓	**2**
(ii)	$(1.51 - 0.85) = 0.66$ (eV) ✓	
(c)	mercury vapour at low pressure is conducting ✓ atoms of mercury are excited by electron impact ✓ producing (mainly) ultra violet radiation ✓ which is absorbed/ excites the coating ✓ which, upon relaxing, produces visible light ✓ electrons cascade down energy levels ✓	**max 3**
	Total	**8**

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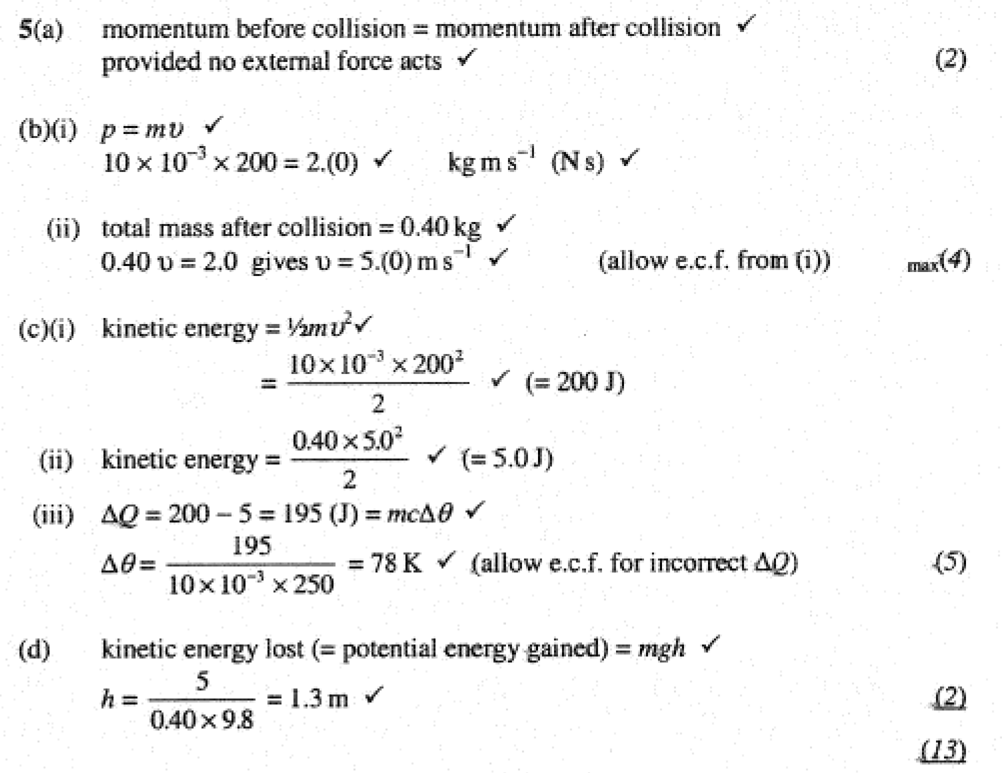
Question 3		
(a)	photons have definite wavelengths/line spectra/frequency ✓ so photons have discrete energies ✓ photons are emitted when electrons/atoms move **down** from one level to another ✓ the energy gaps between energy levels are fixed ✓	**max 3**
(b) (i)	$E_4 = -1.4 \times 10^{-19}$ (J) ✓ use of $hf = E_1 - E_2$ ✓ $hf = (-1.4 \times 10^{-19} - -5.5 \times 10^{-19}) = 4.1 \times 10^{-19}$ J ✓	**4**
(ii)	($f = 4.1 \times 10^{-19}/6.6 \times 10^{-34}$) = 6.2×10^{14} Hz ✓ [possible CE from (i)]	
(c)	6 ✓	**1**
	Total	**8**

Question 5		
(a)	minimum energy ✓ required to remove an electron from a **metal** ✓	**2**
(b) (i)	(using $E = hf$ and $c = f\lambda$) $\lambda = hc/E$ ✓ $= 6.6 \times 10^{-34} \times 3.0 \times 10^{8}/7.9 \times 10^{-19}$ ✓ $= 2.5 \times 10^{-7}$ m ✓	**6**
(ii)	(use of $hf = \phi + E_k$) $\phi = (7.9 \times 10^{-19} - 4.2 \times 10^{-19})$ ✓ $= 3.7 \times 10^{-19}$ (J) ✓	
(iii)	$\phi = 3.7 \times 10^{-19}/1.6 \times 10^{-19}$ = 2.3 (eV) ✓ [possible CE from (ii)]	
(c)	the number of photoelectrons emitted per second will be increased ✓ as the number of incident photons per second is increased ✓ but the **maximum** kinetic energy of the photoelectrons will remain constant ✓ a photon gives up all its energy in one collision ✓	**max 3**
	Total	**11**

Jan 01 P2



5(a) momentum before collision = momentum after collision ✓
provided no external force acts ✓ (2)

(b)(i) $p = m\upsilon$ ✓
$10 \times 10^{-3} \times 200 = 2.(0)$ ✓ kg m s^{-1} (N s) ✓

(ii) total mass after collision = 0.40 kg ✓
$0.40\ \upsilon = 2.0$ gives $\upsilon = 5.(0)$ m s^{-1} ✓ (allow e.c.f. from (i)) $_{\max}(4)$

(c)(i) kinetic energy = $\frac{1}{2}m\upsilon^2$ ✓
$$= \frac{10\times10^{-3}\times200^2}{2}$$ ✓ (= 200 J)

(ii) kinetic energy = $\frac{0.40\times5.0^2}{2}$ ✓ (= 5.0 J)

(iii) $\Delta Q = 200 - 5 = 195$ (J) $= mc\Delta\theta$ ✓
$\Delta\theta = \frac{195}{10\times10^{-3}\times250} = 78$ K ✓ (allow e.c.f. for incorrect ΔQ) (5)

(d) kinetic energy lost (= potential energy gained) = mgh ✓
$h = \frac{5}{0.40\times9.8} = 1.3$ m ✓ (2)

(13)

Jan 03 P2

2

(a) kinetic energy changes to potential energy ✓
potential energy calculated by measuring h ✓
equate kinetic energy to potential energy to find speed ✓
[or use h to find s ✓
use $g \sin\theta$ for a ✓
use $v^2 = u^2 + 2as$ ✓]
[or use h to find s ✓
time to travel s and calculate v_{av} ✓
$v = 2v_{av}$ ✓] (3)

(b)(i) $p\ (= mv) = 0.5(0) \times 0.4(0) = 0.2(0)$ ✓ N s (or kg m s^{-1}) ✓

(b)(ii) (use of $m_p v_p = m_t v_t$ gives) $0.002(0)\ v = 0.2(0)$ ✓
$v = 100$ m s^{-1} ✓ (4)

(c)(i) kinetic energy is not conserved ✓

(c)(ii) initial kinetic energy = $\frac{1}{2} \times 0.002 \times 100^2 = 10$ (J) ✓
final kinetic energy = $\frac{1}{2} \times 0.5 \times 0.4^2 = 0.040$ (J) ✓
hence change in kinetic energy ✓
(allow C.E. for value of v from (b)) (4)

(11)

Jan 04 P2

2

(a)(i) (use of $F = ma$ gives) $1.8 \times 10^3 = 900\,a$ ✓
$a = 2.0\ \mathrm{m\,s^{-2}}$ ✓

(ii) (use of $v = u + at$ gives) $v = 2.0 \times 8.0 = 16\ \mathrm{m\,s^{-1}}$ ✓
(allow C.E. for a from (i))

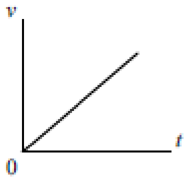
(iii) (use of $p = mv$ gives) $p = 900 \times 16$ ✓
$= 14 \times 10^3\ \mathrm{kg\,m\,s^{-1}}$ (or N s) ✓ ($14.4 \times 10^3\ \mathrm{kg\,m\,s^{-1}}$)
(allow C.E. for v from(ii))

(iv) (use of $s = ut + ½at^2$ gives) $s = \frac{1}{2} \times 2.0 \times 8^2$ ✓
$= 64\ \mathrm{m}$ ✓
(allow C.E. for a from (i))

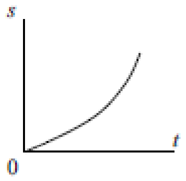
(v) (use of $W = Fs$ gives) $W = 1.8 \times 10^3 \times 64$ ✓
$= 1.2 \times 10^5\ \mathrm{J}$ ✓ ($1.15 \times 10^5\ \mathrm{J}$)
(allow C.E. for s from (iv))

[or $E_K = ½mv^2 = ½ \times 900 \times 16^2$ ✓
$= 1.2 \times 10^5\ \mathrm{J}$ ✓
(allow C.E. for v from (ii))] *(9)*

(b)



✓

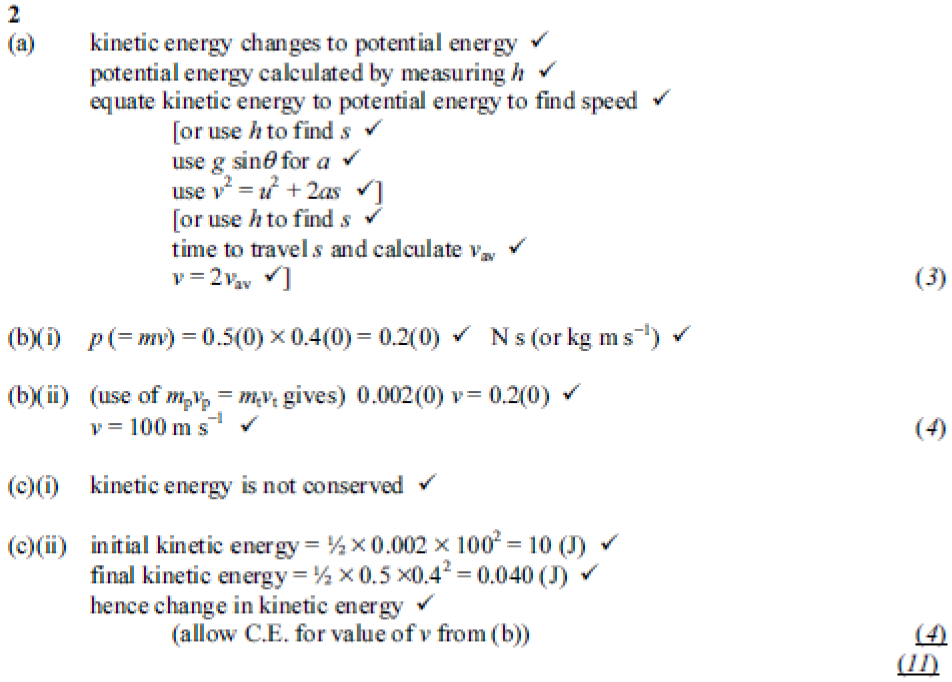


✓ *(2)*

(c)(i) decreases ✓
air resistance increases (with speed) ✓

(ii) eventually two forces are equal (in magnitude) ✓
resultant force is zero ✓
hence constant/terminal velocity (zero acceleration)
in accordance with Newton's first law ✓
correct statement and application of Newton's first or second law ✓ max*(5)*
(16)

Jan 07 P2



2

(a) kinetic energy changes to potential energy ✓
potential energy calculated by measuring h ✓
equate kinetic energy to potential energy to find speed ✓
[or use h to find s ✓
use $g\sin\theta$ for a ✓
use $v^2 = u^2 + 2as$ ✓]
[or use h to find s ✓
time to travel s and calculate v_{av} ✓
$v = 2v_{av}$ ✓] *(3)*

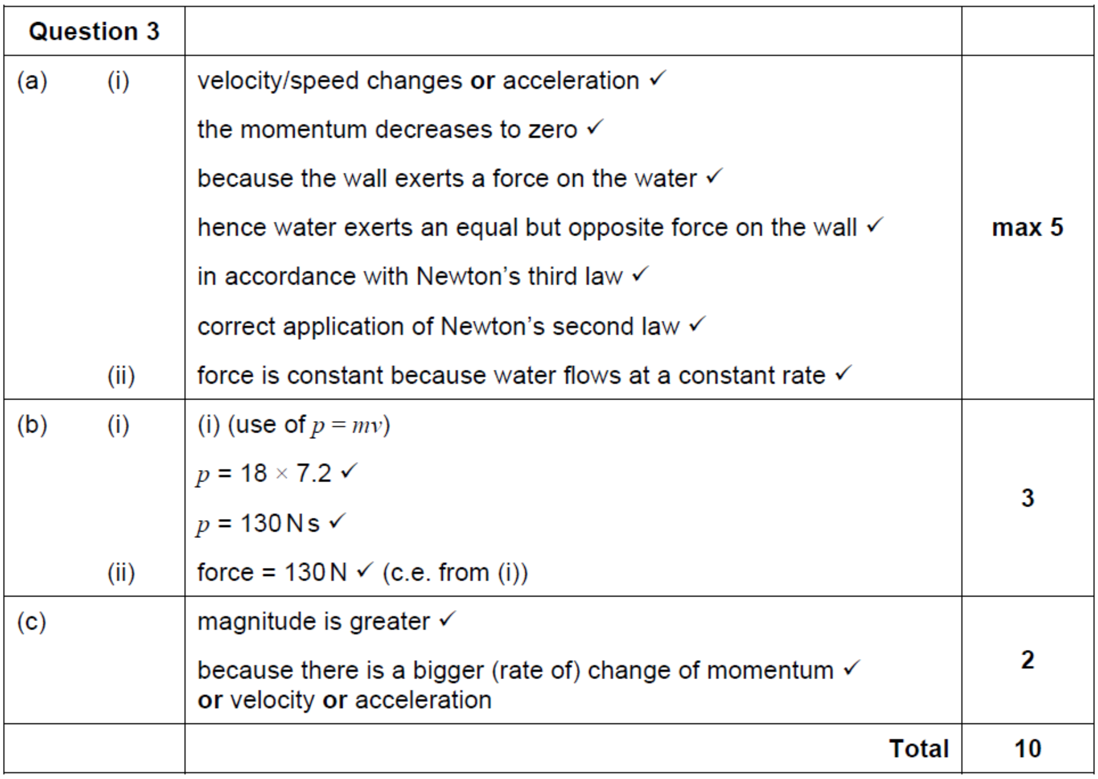
(b)(i) $p\,(= mv) = 0.5(0) \times 0.4(0) = 0.2(0)$ ✓ N s (or kg m s^{-1}) ✓

(b)(ii) (use of $m_p v_p = m_t v_t$ gives) $0.002(0)\ v = 0.2(0)$ ✓
$v = 100$ m s^{-1} ✓ *(4)*

(c)(i) kinetic energy is not conserved ✓

(c)(ii) initial kinetic energy = ½ × 0.002 × 100^2 = 10 (J) ✓
final kinetic energy = ½ × 0.5 ×0.4^2 = 0.040 (J) ✓
hence change in kinetic energy ✓
(allow C.E. for value of v from (b)) *(4)*
(11)

Jan 08 P2



Question 3			
(a)	(i)	velocity/speed changes **or** acceleration ✓ the momentum decreases to zero ✓ because the wall exerts a force on the water ✓ hence water exerts an equal but opposite force on the wall ✓ in accordance with Newton's third law ✓ correct application of Newton's second law ✓	**max 5**
	(ii)	force is constant because water flows at a constant rate ✓	
(b)	(i)	(i) (use of $p = mv$) p = 18 × 7.2 ✓ p = 130 N s ✓	**3**
	(ii)	force = 130 N ✓ (c.e. from (i))	
(c)		magnitude is greater ✓ because there is a bigger (rate of) change of momentum ✓ **or** velocity **or** acceleration	**2**
		Total	**10**

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1(a) kinetic energy is not conserved ✓ (*1*)

(b)(i) ($p = mv$ gives) $p = 0.12 \times 18 = 2.2$ N s ✓ (2.16 N s)

(ii) $p = 0.12 \times (-15) = -1.8$ N s ✓

(iii) $\Delta p = 2.2 - (-1.8) = 4.0$ N s ✓ (3.96 N s)

(allow e.c.f. from (i) and (ii))

(iv) $\left(F = \dfrac{\Delta(mv)}{\Delta t}\right.$ gives) $F = \dfrac{3.96}{0.14}$ ✓

$= 28$ N ✓ (28.3 N)

(allow e.c.f from (iii))

(v) ($E_k = ½mv^2$ gives) $E_k = 0.5 \times 0.12 \times (18^2 - 15^2) = 5.9$ J ✓ (*6*)

(*7*)

Jun 02 P2

4(a)(i) length of card

[or distance travelled by trolley A] ✓

time at which first light gate is obscured

[or time taken to travel the distance] ✓

(ii) time at which second light gate is obscured

[or distance travelled after collision and time taken] ✓ (*3*)

(b) momentum = mass × velocity ✓

mass of each trolley ✓

(check whether) $p_{\text{initial}} = p_{\text{final}}$ ✓ $_{\text{max}}$(*2*)

(c) incline the ramps ✓

until component of weight balances friction ✓

[or identify where the friction occurs ✓

sensible method of reducing ✓] (*2*)

(*7*)

Jun 03 P2

5

(a)(i) acceleration ✓

(a)(ii) both represent acceleration of free fall
[or same acceleration] ✓

(a)(iii) height/distance ball is dropped from above the ground
[or displacement] ✓

(a)(iv) moving in the opposite direction ✓

(a)(v) kinetic energy is lost in the collision
[or inelastic collision] ✓ *(5)*

(b)(i) $v^2 = 2 \times 9.81 \times 1.2$ ✓
$v = 4.9 \text{ m s}^{-1}$ ✓ (4.85 m s^{-1})

(b)(ii) $u^2 = 2 \times 9.81 \times 0.75$ ✓
$u = 3.8 \text{ m s}^{-1}$ ✓ (3.84 m s^{-1})

(b)(iii) change in momentum $= 0.15 \times 3.84 - 0.15 \times 4.85$ ✓
$= -1.3 \text{ kg m s}^{-1}$ ✓ $(1.25 \text{ kg m s}^{-1})$
(allow C.E. from (b)(i) and (b)(ii))

(b)(iv) $F = \dfrac{1.3}{0.10}$ ✓
$= 13 \text{ N}$ ✓
(allow C.E. from (b)(iii)) *(8)*
(13)

Jun 04 P2

6

(a) kinetic energy not conserved ✓
[or velocity of approach is equal to velocity of separation] *(1)*

(b)(i) (use of $p = mv$ gives) $p = 4.5 \times 10^{-2} \times 60$ ✓
$= 2.7 \text{ kg m s}^{-1}$ ✓

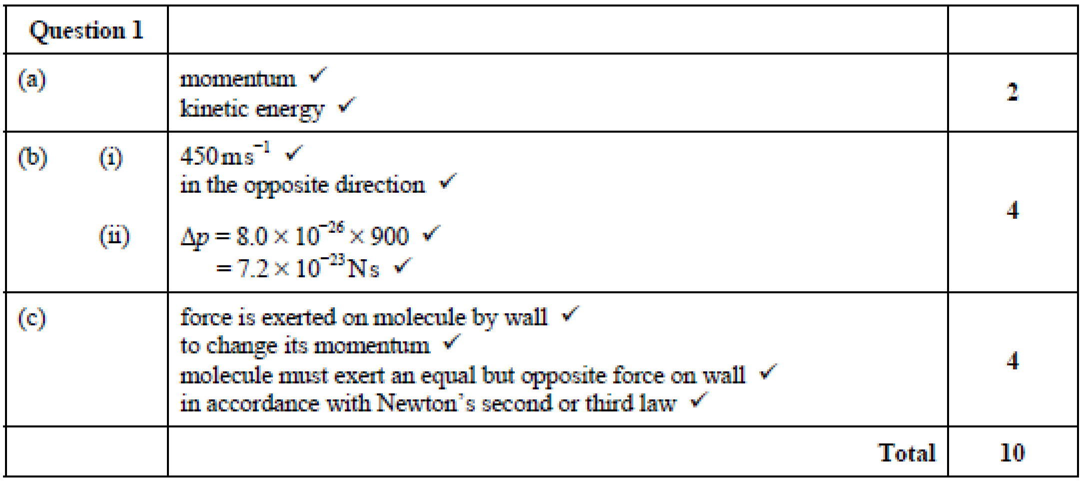
(ii) (use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{2.7}{15 \times 10^{-3}}$ ✓
$= 180 \text{ N}$ ✓

[or $a = \dfrac{v - u}{t} = \dfrac{60}{15 \times 10^{-3}} = 4000 \text{ (m s}^{-1})$
$F = (ma) = 4.5 \times 10^{-2} \times 4000 = 180 \text{ N}$] *(4)*

(c)(i) 180 N ✓
(allow C.E. for value of F from (b) (ii))
in opposite direction (to motion of the club) ✓

(ii) body A (or club) exerts a force on body B (or ball) ✓
(hence) body B (or ball) exerts an equal force on body A (or club) ✓
correct statement of Newton's third law ✓ max *(4)*
(9)

Jun 06 P2



Question 1		
(a)	momentum ✓ kinetic energy ✓	**2**
(b) (i)	$450\,\mathrm{m\,s^{-1}}$ ✓ in the opposite direction ✓	**4**
(ii)	$\Delta p = 8.0 \times 10^{-26} \times 900$ ✓ $= 7.2 \times 10^{-23}\,\mathrm{N\,s}$ ✓	
(c)	force is exerted on molecule by wall ✓ to change its momentum ✓ molecule must exert an equal but opposite force on wall ✓ in accordance with Newton's second or third law ✓	**4**
	Total	**10**