

Q1

5 (a)	(i)	resistance = $V/I$ ..... C1	
		= $6.0/(40 \times 10^{-3})$ = $150 \Omega$ ..... A1	
		(no marks for use of gradient)	
	(ii)	at 8.0 V, resistance = $8.0/(50 \times 10^{-3}) = 160 \Omega$ ..... C1	
		change = $10 \Omega$ ..... A1	[4]
(b)	(i)	straight line through origin ..... M1	
		passes through $I = 40 \text{ mA}$ , $V = 8.0\text{V}$ ..... A1	
	(ii)	current in both must be 40 mA ..... C1	
		e.m.f. = $8.0 + 6.0 = 14.0 \text{ V}$ ..... A1	[4]

Q2.

7 (a)	(i)	$P = VI$ ..... C1	
		current = $60/240 = 0.25 \text{ A}$ $R (= V/I) = 240/0.25$ = $960 \Omega$ ..... A1	
	(ii)		M1
			A0 [3]
(b)		$R = \rho L/A$ (wrong formula, 0/3) ..... C1	
		$960 = (7.9 \times 10^{-7} \times L)/(\pi \times (6.0 \times 10^{-6})^2)$ ..... C1	
		$L = 0.137 \text{ m}$ ..... A1	[3]
		(use of $A = 2\pi r$ , then allow 1/3 marks only for resistivity formula)	
(c)	e.g. the filament must be coiled/it is long for a lamp (allow any sensible comment based on candidate's answer for L)	B1	[1]
<b>Total</b>			<b>[7]</b>

Q3.

8 (a)		$V/E = R/R_{\text{tot}}$ ..... C1	
		$1.0/1.5 = R/(R + 3900)$ ..... M1	
		$R = 7800\Omega$ ..... A0	[2]
(b)		$V = 1.5 \times (7800/(7800 + 1250))$ ..... C1	
		= $1.29 \text{ V}$ ..... A1	[2]
(c)		Combined resistance of R and voltmeter is $3900 \Omega$ ..... C1	
		reading at $0^\circ\text{C}$ is $0.75 \text{ V}$ ..... A1	[2]
<b>Total</b>			<b>[6]</b>

Q4.

6	<p><b>(a) (i)</b> lines normal to plate and equal spacing (at least 4 lines) direction from (+) to earthed plate</p>	B1 B1	[2]
	<p><b>(ii)</b> <math>E = 160/0.08</math> <math>= 2.0 \times 10^3 \text{ V m}^{-1}</math></p>	M1 A0	[1]
	<p><b>(b) (i)</b> correct directions with line of action of arrows passing through charges</p>	B1	[1]
	<p><b>(ii)</b> force <math>= Eq</math> <math>= 2.0 \times 10^3 \times 1.2 \times 10^{-15}</math> <math>= 2.4 \times 10^{-12} \text{ N}</math></p>	C1 A1	[2]
	<p><b>(iii)</b> couple = force <math>\times</math> perpendicular separation <math>= 2.4 \times 10^{-12} \times 2.5 \times 10^{-3} \times \sin 35^\circ</math> <math>= 3.4(4) \times 10^{-15} \text{ N m}</math></p>	M1 A1	[2]
	<p><b>(iv)</b> <u>either rotates</u> to align with the field <u>or oscillates</u> (about a position) with the positive charge nearer to the earthed plate/clockwise</p>	M1 A1	[2]

Q5.

7	<p><b>(a)</b> potential difference/current</p>	B1	[1]
	<p><b>(b) (i)</b> 1) 1.13 W 2) 1.50 V</p>	B1	[1]
	<p><b>(ii)</b> power <math>= V^2 / R</math> or power <math>= VI</math> and <math>V = IR</math> <math>R = 1.50^2 / 1.13</math> <math>= 1.99 \Omega</math></p>	C1 A1	[2]
	<p><b>(iii)</b> <u>either</u> <math>E = IR + Ir</math> or voltage divided between <math>R</math> and <math>r</math> <math>I = 1.5 / 2.0 (=0.75 \text{ A})</math> p.d. across <math>R =</math> p.d. across <math>r = 1.5</math> <math>3.0 = 1.5 + 0.75r</math> <math>r = 2.0 \Omega</math> so <math>R = r = 1.99 \Omega</math></p>	C1 C1 A1	[3]
	<p><b>(c)</b> larger p.d. across <math>R</math> means smaller p.d. across <math>r</math> smaller power dissipation at larger value of <math>V</math> since power is <math>VI</math> and <math>I</math> is same for <math>R</math> and <math>r</math></p>	M1 A1 A1	[3]

Q6.

7	(a) lamp C lamp is shorted	M1 A1	[2]
	(b) shorted lamp A would cause damage to the supply/lamps /blow fuse in supply	B1	[1]
	(c) 15 $\Omega$	B1	[1]
	(d) (i) $V = IR$ $R = 30 \Omega$	C1 A1	[2]
	(ii) $P = VI$ or $I^2R$ or $V^2/R$ $P = 1.2 \text{ W}$	C1 A1	[2]
	(e) filament is cold when measuring with ohm-meter in (b) resistance of filament rises as temperature rises	B1 B1	[2]

**Q7.**

2	(a) force per unit positive charge (on a small test charge)	B1	[1]
	(b) field strength = $(210 / \{1.5 \times 10^{-2}\}) = 1.4 \times 10^4 \text{ N C}^{-1}$	A1	[1]
	(c) (i) acceleration = $Eq / m$ $= (1.4 \times 10^4 \times 1.6 \times 10^{-19}) / (9.1 \times 10^{-31})$ $= 2.5 \times 10^{15} \text{ m s}^{-2}$ (2.46 $\times 10^{15}$ ) towards positive plate / upwards (and normal to plate)	C1 C1 A1 B1	[4]
	(ii) time = $2.4 \times 10^{-9} \text{ s}$	A1	[1]
	(d) either vertical displacement after acceleration for $2.4 \times 10^{-9} \text{ s}$ $= \frac{1}{2} \times 2.46 \times 10^{15} \times (2.4 \times 10^{-9})^2$ $= 7.1 \times 10^{-3} \text{ m}$ (0.71 cm < 0.75 cm and) so will pass between plates <i>i.e. valid conclusion based on a numerical value</i>	C1 A1 A1	[3]
	or $0.75 \times 10^{-2} = \frac{1}{2} \times 2.46 \times 10^{15} \times t^2$ $t$ is time to travel 'half-way across' plates = $2.47 \times 10^{-9} \text{ s}$ (2.4 ns < 2.47 ns) so will pass between plates <i>i.e. valid conclusion based on a numerical value</i>	(C1) (A1) (A1)	

**Q8.**

<b>6 (a) (i)</b>	1 total resistance = 0.16 $\Omega$	A1	
	2 e.m.f. = either (14 - E) or (E - 14)	A1	[2]
<b>(ii)</b>	either 14 - E = 42 $\times$ 0.16 or (E - 14) = -42 $\times$ 0.16	C1	
	E = 7.3 V	A1	[2]
<b>(b) (i)</b>	charge = It	C1	
	= 12.5 $\times$ 4 $\times$ 60 $\times$ 60		
	= 1.8 $\times$ 10 <sup>5</sup> C	A1	[2]
<b>(ii)</b>	either energy = EQ or energy = Eit	C1	
	either energy = 14 $\times$ 1.8 $\times$ 10 <sup>5</sup> or energy = 14 $\times$ 12.5 $\times$ 4 $\times$ 3600		
	= 2.52 $\times$ 10 <sup>6</sup> J	A1	[2]
<b>(iii)</b>	energy = I <sup>2</sup> Rt or Vit and V = IR	C1	
	= 12.5 <sup>2</sup> $\times$ 0.16 $\times$ 4 $\times$ 3600		
	= 3.6 $\times$ 10 <sup>5</sup> J	A1	[2]
<b>(c)</b>	efficiency = (2.52 $\times$ 10 <sup>6</sup> - 3.6 $\times$ 10 <sup>5</sup> ) / (2.52 $\times$ 10 <sup>6</sup> )	C1	
	= 86%	A1	[2]

**Q9.**

<b>6 (a)</b>	either P = VI and V = IR or P = V <sup>2</sup> /R	C1	
	resistance = 38.4 $\Omega$	A1	[2]
<b>(b)</b>	zero	B1	
	1.5 kW	B1	
	3.0 kW	B1	
	0.75 kW	B1	
	2.25 kW	B1	[5]

**Q10.**

6	(a)	(i)	$E = V/d$ .....	C1	
			$= 350 / (2.5 \times 10^{-2})$		
			$= 1.4 \times 10^4 \text{ N C}^{-1}$ .....	A1	[2]
	(ii)	force = $Eq$ .....	C1		
		$= 1.4 \times 10^4 \times 1.6 \times 10^{-19}$ .....	M1		
		$= 2.24 \times 10^{-15}$ .....	A0	[2]	
6	(b)	(i)	$F = ma$ .....	C1	
			$a = (2.24 \times 10^{-15}) / (9.1 \times 10^{-31})$		
			$= 2.46 \times 10^{15} \text{ m s}^{-2}$ ... (allow $2.5 \times 10^5$ ) .....	A1	[2]
	(ii)	$s = \frac{1}{2}at^2$ .....	C1		
		$2.5 \times 10^{-2} = \frac{1}{2} \times 2.46 \times 10^{15} \times t^2$			
		$t = 4.5 \times 10^{-9} \text{ s}$ .....	A1	[2]	
	(c)	either gravitational force is normal to electric force or electric force horizontal, gravitational force vertical .....	B2	[2]	
		special case: force/acceleration due to electric field $\gg$ force/acceleration due to gravitational field, allow 1 mark			

Q11.

7	(a)	(i)	$R$ .....	B1	[1]
		(ii)	$0.5R$ .....	B1	[1]
		(iii)	$2.5R$ ... (allow e.c.f. from (ii)) .....	B1	[1]
7	(b)	(i)	$I_1 + I_2 = I_3$ .....	B1	[1]
		(ii)	$E_2 = I_3R + I_2R$ .....	B1	[1]
		(iii)	$E_1 - E_2 = 2I_1R - I_2R$ .....	B1	[1]

Q12.

7	(a)	$\infty$ .....	A1		
		$2R$ .....	A1		
		$R$ .....	A1	[3]	
7	(b)	(i)	$I_1 + I_3 = I_2 + I_4$ .....	A1	[1]
		(ii)	$E_2 - E_1 = I_3R$ .....	A1	[1]
		(iii)	$E_2 = I_3R + 2I_4R$ .....	A1	[1]

Q13.

- 5 (a) region/area where a charge experiences a force ..... B1 [1]
- (b) (i) left-hand sphere (+), right-hand sphere (-) ..... B1 [1]
- (ii) 1 correct region labelled C within 10 mm of central part of plate  
otherwise within 5 mm of plate ..... B1 [1]
- 2 correct region labelled D area of field not included for (b)(ii)1 ..... B1 [1]
- (c) (i) arrows through P and N in correct directions ..... B1 [1]
- (ii) torque = force  $\times$  perpendicular distance (between forces) ..... C1  
 $= 1.6 \times 10^{-19} \times 5.0 \times 10^4 \times 2.8 \times 10^{-10} \times \sin 30$   
 $= 1.1 \times 10^{-24} \text{ N m}$  ..... A1 [2]

Q14.

- 6 (a) (i)  $P = VI$  ..... C1  
 $60 = 12 \times I$   
 $I = 5.0 \text{ A}$  ..... A1 [2]
- (ii) either  $V = IR$  or  $P = I^2 R$  or  $P = V^2 / R$  ..... C1  
either  $12 = 5 \times R$  or  $60 = 5^2 \times R$  or  $60 = 12^2 / R$  ..... M1  
 $R = 2.4 \Omega$  ..... A0 [2]
- (b)  $R = \rho L / A$  ..... C1  
 $A = \pi \times (0.4 \times 10^{-3})^2 (= 5.03 \times 10^{-7})$  ..... C1  
 $L = (2.4 \times 5.03 \times 10^{-7}) / (1.0 \times 10^{-6})$   
 $= 1.2 \text{ m}$  ..... A1 [3]
- (c) resistance is halved ..... M1  
either current is doubled or power  $\propto 1/R$  ..... M1  
power is doubled ..... A1 [3]

Q15.

6 (a)	either $P \propto V^2$ or $P = V^2/R$ .....	C1	
	reduction = $(230^2 - 220^2)/230^2$ = 8.5% .....	A1	[2]
(b) (i)	zero .....	A1	[1]
	(ii) 0.3(0)A .....	A1	[1]
(c) (i)	correct plots to within $\pm 1$ mm .....	B1	[1]
	(ii) reasonable line/curve through points giving current as 0.12 A allow $\pm 0.005$ A) .....	B1	[1]
	(iii) $V = IR$ .....	C1	
	$V = 0.12 \times 5.0$ = 0.6(0)V .....	A1	[2]
(d)	circuit acts as a potential divider/current divides/current in AC not the same as current in BC .....	B1	
	resistance between A and C not equal to resistance between C and B .....	B1	
	or current in wire AC $\times R$ is not equal to current in wire BC $\times R$ any 2 statements	B1	[2]

Q16.

6 (a) (i)	movement/flow of charged particles	B1	[1]
	(ii) work done per unit charge (transferred)	B1	[1]
(b)	straight line through origin	B1	
	resistance = $V/I$ , with values for $V$ and $I$ shown = $20 \Omega$	M1 A0	[2]
	(using the gradient loses the last mark)		
(c) (i)	0.5A	A1	[1]
	(ii) either resistance of each resistor is $20 \Omega$ or total current = 0.8A either combined resistance = $10 \Omega$ or $R = E/I = 10 \Omega$	C1 A1	[2]
(d) (i)	10V	A1	[1]
	(ii) power = $EI$ = $10 \times 0.2 = 2.0$ W	C1 A1	[2]

Q17.

- 5 (a) (i)  $I = 12 / (6 + 12)$   
minimum current = 0.67 A C1  
A1 [2]
- (ii) correct start and finish points M1  
correct shape for curve with decreasing gradient A1 [2]
- (b) maximum current = 2.0 A A1  
minimum current = 0 A1 [2]
- (c) (i) smooth curve starting at (0,0) with decreasing gradient M1  
end section not horizontal A1 [2]
- (ii) full range of current / p.d. possible  
or currents / p.d. down to zero  
or brightness ranging from off to full brightness B1 [1]

### Q18.

- 5 (a) (i) energy converted from chemical to electrical when charge flows through cell  
or round complete circuit B1
- (ii) (resistance of the cell) causing loss of voltage or energy loss in cell B1 [2]
- (b) (i)  $E_B - E_A = I(R + r_B + r_A)$   
 $12 - 3 = I(3.3 + 0.1 + 0.2)$   
 $I = 2.5 \text{ A}$  C1  
A1 [2]
- (ii) Power =  $E \times I$   
 $= 12 \times 2.5$   
 $= 30 \text{ W}$  C1  
A1 [2]
- (iii)  $P = I^2 \times R$  or  $P = V^2 / R$  or  $P = VI$   
 $= (2.5)^2 \times 3$   $= 9^2 / 3.6$   $= 9 \times 2.5$   
 $= 22.5 \text{ J s}^{-1}$  C1  
A1 [2]
- (c) power supplied from cell B is greater than energy lost per second in circuit B1 [1]

### Q19.

- 5 (a) (i) Start from (0,0) and smooth curve in correct direction B1  
Curve correct for end section never horizontal B1 [2]
- (ii)  $R = V / I$  hence take co-ords of  $V$  and  $I$  from graph and calculate  $V / I$  B1 [1]
- (b) (i) each lamp in parallel has a greater p.d. / greater current M1  
lamp hotter M1  
resistance of lamps in parallel greater A1 [3]
- (ii)  $P = V^2 / R$  or  $P = VI$  and  $V = IR$   
 $R = 144 / 50 = 2.88$  for each lamp C1  
total  $R = 1.44 \Omega$  C1  
A1 [3]



**Q20.**

- 4 (a) (i)**  $R = V^2 / P$  or  $P = IV$  and  $V = IR$   
 $= (220)^2 / 2500$   
 $= 19.4 \Omega$  (allow 2 s.f.)
- (ii)**  $R = \rho l / A$   
 $l = [19.4 \times 2.0 \times 10^{-7}] / 1.1 \times 10^{-6}$   
 $= 3.53 \text{ m}$  (allow 2 s.f.)
- (b) (i)**  $P = 625, 620$  or  $630 \text{ W}$
- (ii)**  $R$  needs to be reduced  
*Either* length  $\frac{1}{4}$  of original length  
or area  $4\times$  greater  
or diameter  $2\times$  greater

**Q21.**

- 5 (a) (i)** sum of e.m.f.'s = sum of p.d.'s around a loop/circuit
- (ii)** energy
- (b) (i)**  $2.0 = I \times (4.0 + 2.5 + 0.5)$   
 $I = 0.286 \text{ A}$  (allow 2 s.f.)  
*(If total resistance is not  $7 \Omega$ , 0/2 marks)*
- (ii)**  $R = [0.90 / 1.0] \times 4 (= 3.6)$   
 $V = I R = 0.286 \times 3.6 = 1.03 \text{ V}$   
*(If factor of 0.9 not used, then 0/2 marks)*
- (iii)**  $E = 1.03 \text{ V}$
- (iv)** *either* no current through cell B  
or p.d. across  $r$  is zero

**Q22.**

- 4 (a)** total resistance =  $20 \text{ (k}\Omega)$   
current =  $12 / 20 \text{ (mA)}$  or potential divider formula  
p.d. =  $[12 / 20] \times 12 = 7.2 \text{ V}$
- (b)** parallel resistance =  $3 \text{ (k}\Omega)$   
total resistance  $8 + 3 = 11 \text{ (k}\Omega)$   
current =  $12 / 11 \times 10^3 = 1.09 \times 10^{-3}$  or  $1.1 \times 10^{-3} \text{ A}$
- (c) (i)** LDR resistance decreases  
total resistance (of circuit) is less hence current increases
- (ii)** resistance across XY is less  
less proportion of  $12 \text{ V}$  across XY hence p.d. is less

**Q23.**

- 4 (a) electric field strength is the force per unit positive charge (acting on a stationary charge) B1 [1]
- (b) (i)  $E = V / d$  C1  
 $= 1200 / 14 \times 10^{-3}$   
 $= 8.57 \times 10^4 \text{ V m}^{-1}$  A1 [2]
- (ii)  $W = QV$  or  $W = F \times d$  and therefore  $W = E \times Q \times d$  C1  
 $= 3.2 \times 10^{-19} \times 1200$   
 $= 3.84 \times 10^{-16} \text{ J}$  A1 [2]
- (iii)  $\Delta U = mgh$  C1  
 $= 6.6 \times 10^{-27} \times 9.8 \times 14 \times 10^{-3}$   
 $= 9.06 \times 10^{-28} \text{ J}$  A1 [2]
- (iv)  $\Delta K = 3.84 \times 10^{-16} - \Delta U$   
 $= 3.84 \times 10^{-16} \text{ J}$  A1 [1]
- (v)  $K = \frac{1}{2}mv^2$  C1  
 $v = [(2 \times 3.8 \times 10^{-16}) / 6.6 \times 10^{-27}]^{1/2}$   
 $= 3.4 \times 10^5 \text{ ms}^{-1}$  A1 [2]

#### Q24.

- 5 (a) (i) sum of currents into a junction = sum of currents out of junction B1 [1]
- (ii) charge B1 [1]
- (b) (i)  $\Sigma E = \Sigma IR$  C1  
 $20 - 12 = 2.0(0.6 + R)$  (not used 3 resistors 0/2)  
 $R = 3.4 \Omega$  A1 [2]
- (ii)  $P = EI$  C1  
 $= 20 \times 2$   
 $= 40 \text{ W}$  A1 [2]
- (iii)  $P = I^2 R$  C1  
 $P = (2)^2 \times (0.1 + 0.5 + 3.4)$   
 $= 16 \text{ W}$  A1 [2]
- (iv) efficiency = useful power / output power C1  
 $24 / 40 = 0.6$  or  $12 \times 2 / 20 \times 2$  or 60% A1 [2]

#### Q25.

- 6 (a) (i) chemical to electrical B1 [1]  
(ii) electrical to thermal / heat or heat and light B1 [1]
- (b) (i)  $(P_B =) EI$  or  $I^2(R_1 + R_2)$  A1 [1]  
(ii)  $(P_R =) I^2R_1$  A1 [1]
- (c)  $R = \rho l / A$  or clear from the following equation B1  
ratio =  $I^2R_1 / I^2R_2 = \frac{\rho l / \pi d^2}{\rho(2l) / \pi(2d)^2}$  or  $R_1$  has 8× resistance of  $R_2$  C1  
= 8 or 8:1 A1 [3]
- (d)  $P = V^2 / R$  or  $E^2 / R$  C1  
(V or E the same) hence ratio is 1/8 or 1:8 = 0.125 (allow ecf from (c)) A1 [2]

### Q26.

- 6 (a) charge = current × time B1 [1]
- (b) (i)  $P = V^2 / R$  C1  
=  $(240)^2 / 18 = 3200\text{W}$  A1 [2]
- (ii)  $I = V / R = 240 / 18 = 13.3\text{A}$  A1 [1]
- (iii) charge =  $It = 13.3 \times 2.6 \times 10^6$  C1  
=  $3.47 \times 10^7\text{C}$  A1 [2]
- (iv) number of electrons =  $3.47 \times 10^7 / 1.6 \times 10^{-19}$  (=  $2.17 \times 10^{26}$ ) C1  
number of electrons per second =  $2.17 \times 10^{26} / 2.6 \times 10^6 = 8.35 \times 10^{19}$  A1 [2]

### Q27.

- 6 (a) p.d. =  $\frac{\text{work done} / \text{energy transformed}}{\text{charge}}$  (from electrical to other forms) B1 [1]
- (b) (i) maximum 20V A1 [1]  
(ii) minimum =  $(600 / 1000) \times 20$  C1  
= 12V A1 [2]
- (c) (i) use of 1.2kΩ M1  
 $1/1200 + 1/600 = 1/R$ ,  $R = 400\Omega$  A1 [2]
- (ii) total parallel resistance ( $R_2 + \text{LDR}$ ) is less than  $R_2$  M1  
(minimum) p.d. is reduced A1 [2]

### Q28.

- 6 (a) (i) arrow in upward direction, foot near P ..... B1  
(ii) curved path consistent with (i) between plates ..... B1  
then straight (with no kink at change-over) ..... B1 [3]
- (b)  $E = V/d$  ..... C1  
 $= 400 / (0.8 \times 10^{-2})$   
 $= 5.0 \times 10^4 \text{ V m}^{-1}$  ..... (allow 1 sig fig) ..... A1 [2]
- (c) (i)  $F = Eq$  ..... C1  
 $= 5.0 \times 10^4 \times 1.6 \times 10^{-19}$   
 $= 8.0 \times 10^{-15} \text{ N}$  ..... (allow 1 sig fig and e.c.f.) ..... A1
- (ii)  $a = F/m$  ..... C1  
 $= (8.0 \times 10^{-15}) / (9.1 \times 10^{-31})$   
 $= 8.8 \times 10^{15} \text{ m s}^{-2}$  ..... (allow 1 sig fig and e.c.f.) ..... A1 [4]
- (d) because  $F_E$  is normal to horizontal motion ..... M1  
no effect ..... A1 [2]

Q29.

- 7 (a) (i) e.m.f. = energy / charge ..... C1  
 $= (1.6 \times 10^5) / (1.8 \times 10^4)$   
 $= 8.9 \text{ V}$  ..... A1
- (ii) current =  $\Delta Q / \Delta t$  ..... C1  
 $= (1.80 \times 10^4) / (1.3 \times 10^5)$   
 $= 0.14 \text{ A}$  ..... A1 [4]
- (b) (i) energy  $\propto R$  (or formula) ..... C1  
energy =  $(15 / 45) \times 1.14 \times 10^5$  ..... C1  
 $= 3.7 \times 10^4 \text{ J}$  ..... A1
- (ii) energy dissipated in internal resistance (of battery) ..... B1 [4]  
OR in extra resistance in circuit

Q30.

- 5 (a) (i) arrow from B towards A..... B1
- (ii)  $E = V/d$   
 $= 450/(9.0 \times 10^{-2})$  ..... C1  
 $= 5.0 \times 10^3 \text{ N C}^{-1}$  (accept 1 sig. fig) ..... A1 [3]
- (b) (i) energy =  $qV$  or  $Eqd$  ..... C1  
 $= 1.6 \times 10^{-19} \times 450$ ..... A1  
 $= 7.2 \times 10^{-17} \text{ J}$ ..... A0
- (ii)  $E_k = \frac{1}{2}mv^2$   
 $7.2 \times 10^{-17} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$  ..... C1  
 $v = 1.26 \times 10^7 \text{ m s}^{-1}$  ..... A1 [4]
- (c) line from origin, curved in correct direction but not 'level out' ..... B1 [1]

Q31.

- 7 (a) (i)  $P = Vi$  ..... C1  
 $1200 = 240 \times i$  ..... M1  
 $i = 5.0 \text{ A}$  ..... A0
- (ii)  $V = iR$   
 $240 = 5.0 \times R$  ..... C1  
 $R = 48\Omega$  ..... A1 [4]
- (b) (i) p.d. =  $(5.0 \times 4.0 =) 20 \text{ V}$  ..... A1
- (ii) mains voltage =  $(240 + 20 =) 260 \text{ V}$  ..... A1
- (iii)  $P = (20 \times 5.0 =) 100 \text{ W}$  ..... A1 [3]
- (c) power input =  $1200 + 100 = 1300 \text{ W}$  ..... C1  
efficiency =  $1200/1300 = 0.92$  ..... A1 [2]

Q32.

- 6 (a) (i) resistance is ratio  $V/I$  (at a point) B1  
*either gradient increases or  $I$  increases more rapidly than  $V$*  B1 [2]  
*(If states  $R = \text{reciprocal of gradient}$ , then 0/2 marks here)*
- (ii) current = 2.00 mA C1  
resistance = 2 000  $\Omega$  A1 [2]
- (b) (i) straight line from origin M1  
passing through (6.0 V, 4.0 mA) (allow  $\frac{1}{2}$  square tolerance) A1 [2]
- (ii) individual currents are 0.75 mA and 1/33 mA C1  
current in battery = 2.1 mA A1 [2]  
*(allow argument in terms of  $P = I^2R$  or  $IV$ )*
- (c) same current in R and in C M1  
p.d. across C is larger than that across R M1  
so since power =  $VI$ , greater in C A1 [3]  
*(allow argument in terms of  $P = I^2R$  or  $IV$ )*

### Q33.

- 6 (a) force must be upwards (on positive charge)  
so plate Y is positive M1  
A1 [2]
- (b) (i)  $E = V / d$  C1  
 $= 630 / (0.75 \times 10^{-2})$   
 $= 8.4 \times 10^4 \text{ N C}^{-1}$  A1 [2]
- (ii)  $qE = mg$  C1  
 $q = (9.6 \times 10^{-15} \times 9.8) / (8.4 \times 10^4)$  C1  
 $= 1.12 \times 10^{-18} \text{ C}$  A1 [3]

### Q34.

- 7 (a) *either*  $V = E R_1 / (R_1 + R_2)$  *or*  $I = E / (R_1 + R_2)$  C1  
 $= \frac{1800}{3000} \times 4.50$   $V = \frac{1800}{3000} \times 4.50$  M1  
 $= 2.70 \text{ V}$   $= 2.70 \text{ V}$  A0 [2]
- (b) (i) for a wire,  $V = I \times (\rho L/A)$  M1  
 $I, \rho$  and  $A$  are constant A1  
so  $V \propto L$  A0 [2]

- (ii) 1 2.70 V A1 [1]  
 2  $\frac{L}{100} = \frac{2.70}{4.50}$  C1  
 $L = 60.0 \text{ cm}$  A1 [2]  
 (iii) thermistor resistance decreases as temperature rises M1  
 so QM is shorter A1 [2]

Q35.

- 7 (a) both measure (energy / work) / charge B1  
 for e.m.f., transfer of chemical energy to electrical energy B1  
 for p.d., transfer of electrical energy to thermal energy / other forms B1 [3]  
 (b) (i)  $I_1 + I_2 = I_3$  B1 [1]  
 (ii) 1.  $E_2 = I_2 R_2 + I_3 R_3$  B1 [1]  
 2.  $E_1 - E_2 = I_1 R_1 - I_2 R_2$  B1 [1]

Q36.

- 6 (a) power =  $VI$  C1  
 current =  $10.5 \times 103 / 230$  M1  
 $= 45.7 \text{ A}$  A0 [2]  
 (b) (i) p.d. across cable = 5.0 V C1  
 $R = 5.0 / 46$  C1  
 $= 0.11 \Omega$  A1 [3]  
 (ii)  $R = \rho L / A$  C1  
 $0.11 = (1.8 \times 10^{-8} \times 16 \times 2) / A$  C1  
 $A = 5.3 \times 10^{-6} \text{ m}^2$  A1 [3]  
 (wires in parallel, not series, allow max 1/3 marks)  
 (c) (i) either power =  $V^2 / R$  or power  $\propto V^2$  C1  
 ratio =  $(210 / 230)^2 = 0.83$  A1 [2]  
 (ii) resistance of cable is greater M1  
 greater power loss/fire hazard/insulation may melt  
 wire may melt/cable gets hot A1 [2]

Q37.

- 4 (a) (i) either force =  $e \times (V / d)$  or  $E = V/d$  C1  
 $= 1.6 \times 10^{-19} \times (250 / 7.6 \times 10^{-3})$  C1  
 $= 5.3 \times 10^{-15} \text{ N}$  A1 [3]  
 (ii) either  $\Delta E_k = eV$  or  $\Delta E_k = Fd$  C1  
 $= 1.6 \times 10^{-19} \times 250$  M1  
 $= 4.0 \times 10^{-17} \text{ J}$  A0 [2]  
 $= 5.3 \times 10^{-15} \times 7.6 \times 10^{-3}$   
 (allow full credit for correct working via calculation of a and v)

- (iii) either  $\Delta E_K = \frac{1}{2}mv^2$   
 $4.0 \times 10^{-17} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$  C1  
 $v = 9.4 \times 10^6 \text{ m s}^{-1}$  A1 [2]
- or  $v^2 = 2as$  and  $a = F/m$   
 $v^2 = (2 \times 5.3 \times 10^{-15} \times 7.6 \times 10^{-3}) / (9.11 \times 10^{-31})$  (C1)  
 $v = 9.4 \times 10^6 \text{ m s}^{-1}$  (A1)
- (b) speed depends on (electric) potential difference M2  
*(If states  $\Delta E_K$  does not depend on uniformity of field, then*  
*award 1 mark, treated as an M mark)*  
 so speed always the same A1 [3]

**Q38.**

- 7 (a) either  $V = IP$  B1  
 current in circuit =  $E / (P + Q)$  B1  
 hence  $V = EP / (P + Q)$  A0 [2]
- or current is the same throughout the circuit (M1)  
 $V/P = E/(P + Q)$  (A1)  
 hence  $V = EP / (P + Q)$  (A0)
- (b) (i) (as temperature rises), resistance of (thermistor) decreases M1  
 either resistance of parallel combination decreases  
 or p.d. across 5 k $\Omega$  resistor / thermistor decreases M1  
 p.d. across 2000  $\Omega$  resistor / voltmeter reading increases A1 [3]
- (ii) if  $R$  is the resistance of the parallel combination,  
 either  $3.6 = (2 \times 6) / (2 + R)$  or current in 2 k $\Omega$  resistor = 1.8 mA C1  
 $R = 1.33 \text{ k}\Omega$  current in 5 k $\Omega$  resistor = 0.48 mA C1  
 $\frac{1}{1.33} = \frac{1}{5} + \frac{1}{T}$  current in thermistor = 1.32 mA C1  
 $T = 1.82 \text{ k}\Omega$   $T = 2.4 / 1.32 = 1.82 \text{ k}\Omega$  A1 [4]

**Q39.**

- 6 (a) energy transferred from source / changed from some form to electrical .....M1  
 per unit charge (to drive charge round a complete circuit) ..... A1 [2]
- (b) and power in  $R = I^2X$  .....M1  
 $E = I(X + r)$  .....M1  
 power in cell =  $EI$  and algebra clear leading to ratio =  $X / (X + r)$  ..... A1 [3]



- (c) (i) 1.4 W ..... A1  
 0.40  $\Omega$  .....(allow  $\pm 0.05 \Omega$ ) ..... A1 [2]
- (ii) current in circuit =  $\sqrt{1.4/0.4} = 1.87 \text{ A}$  ..... C1  
 1.5 = 1.87 ( $r + 0.40$ ) ..... C1  
 $r = 0.40 \Omega$  ..... A1 [3]
- (d) either less power lost / energy wasted / lost ..... B1 [1]  
 or greater efficiency (of energy transfer) .....

[Total: 11]

Q40.

- 
- 6 (a) total resistance in series =  $2R$  ..... M1  
 total resistance in parallel =  $\frac{1}{2}R$  ..... A0 [1]  
 ratio is  $2R / \frac{1}{2}R = 4$  .....(allow mark if clear numbers in the ratio) .....
- (b) at 1.5 V, current is 0.10 A ..... C1  
 resistance =  $V/I = \frac{1.5}{0.1}$  ..... A1 [2]  
 = 15  $\Omega$  .....  
 (use of tangent or any other current scores no marks)

(c)

	p.d. across each lamp / V	resistance of each lamp / $\Omega$	combined resistance / $\Omega$
series	1.5	15	30
parallel	3.0	20	10

- column 1 ..... A1  
 columns 2 and 3: max 3 marks with -1 mark for each error or omission ..... A3 [4]
- (d) (i) ratio is 3 .....(allow e.c.f.) ..... A1 [1]
- (ii) resistance increases as potential difference increases ..... B1  
 increasing p.d. increases current ..... B1  
 current increases non-linearly so resistance increases ..... B1 [3]

[Total: 11]

Q41.

- 6 (a) (i) either  $P = V^2 / R$  or  $P = VI$  and  $V = IR$   
 $R = 4.0 \Omega$  C1  
A1 [2]
- (ii) sketch vertical axis labelled appropriately B1  
(staight) line from origin then curved in correct direction B1  
line passes through 12 V, 3.0 A B1 [3]
- (b) (i) 2.0 kW A1 [1]
- (ii) 0.5 kW A1 [1]
- (iii) total resistance =  $3R / 2$  C1  
power = 0.67 kW A1 [2]

#### Q42.

- 6 (a) (i) at 22.5 °C,  $R_T = 1600 \Omega$  or 1.6 k $\Omega$  C1  
total resistance = 800  $\Omega$  A1 [2]
- (ii) either use of potential divider formula or current = 9 / 2000 (4.5 mA) C1  
 $V = (0.8/2.0) \times 9$   $V = (9/2000) \times 800$   
= 3.6V = 3.6V A1 [2]
- (b) (i) total resistance =  $4/5 \times 1200$  C1  
= 960  $\Omega$  A1 [2]
- (ii) for parallel combination,  $1/960 = 1/1600 + 1/R_T$  C1  
 $R_T = 2400 \Omega$  / 2.4 k $\Omega$  A1 [2]  
temperature = 11 °C
- (c) e.g. only small part of scale used / small sensitivity B1  
non-linear B1 [2]  
(any two sensible suggestions, 1 each, max 2)

#### Q43.

- 7 (a) (i) path: reasonable curve upwards between plates  
straight and at a tangent to the curve beyond the plates B1  
B1 [2]
- (ii) 1.  $(F =) Eq$  B1 [1]  
2.  $(t =) L/v$  B1 [1]
- (b) (i) total momentum of a system remains constant or total momentum of a system before a collision equals total momentum after collision provided no external force acts on the system M1  
(do not accept 'conserved' but otherwise correct statement gets 1/2) A1 [2]
- (ii)  $(\Delta p =) EqL/v$  allow ecf from (a)(ii) B1 [1]
- (iii) either charged particle is not an isolated system M1  
so law does not apply A1 [2]  
or system is particle and 'plates' (M1)  
equal and opposite  $\Delta p$  on plates / so law applies (A1)

#### Q44.

- 8 (a) (i) either  $P = V^2 / R$  or  $I = 1200 / 230$  or 5.22 C1  
 $R = 230^2 / 1200$  or  $R = (230 \times 230) / 1200$  M1  
 $= 44.1 \Omega$  or  $R = 230 / 5.22$  A0 [2]  
 $= 44.1 \Omega$
- (ii)  $R = \rho L / A$  C1  
 $= (1.7 \times 10^{-8} \times 9.2 \times 2) / (\pi \times \{0.45 \times 10^{-3}\}^2)$  M1  
 $= 0.492 \Omega$  A0 [2]
- (b) current =  $230 / 44.6$  C1  
power =  $(230 / 44.6)^2 \times 44.1$  C1  
 $= 1170 \text{ W}$  A1 [3]  
(allow full credit for solution based on potential divider)
- (c) e.g. less power dissipated in the heater / smaller p.d. across heater / more power loss in cable / current lower B1  
cable becomes heated / melts B1 [2]  
(any two sensible suggestions, 1 each, max 2)

#### Q45.

- 5 (a) ohm = volt / ampere B1 [1]
- (b)  $\rho = RA / l$  or unit is  $\Omega m$  C1  
units:  $VA^{-1} m^2 m^{-1} = NmC^{-1} A^{-1} m^2 m^{-1}$  C1  
 $= kgm^2 s^{-2} A^{-1} s^{-1} A^{-1} m^2 m^{-1}$   
 $= kgm^3 s^{-3} A^{-2}$  A1 [3]
- (c) (i)  $\rho = [3.4 \times 1.3 \times 10^{-7}] / 0.9$  C1  
 $= 4.9 \times 10^{-7} (\Omega m)$  A1 [2]
- (ii) max = 2.0 V A1  
min =  $2 \times (3.4 / 1503.4) = 4.5 \times 10^{-3} V$  A1 [2]
- (iii)  $P = V^2 / R$  or  $P = VI$  and  $V = IR$  C1  
 $= (2)^2 / 3.4$   
 $= 1.18$  (allow 1.2) W A1 [2]
- (d) (i) power in Q is zero when  $R = 0$  B1 [1]
- (ii) power in Q = 0 / tends to zero as  $R =$  infinity B1 [1]

#### Q46.

- 4 (a) electric field strength = force / positive charge B1 [1]
- (b) (i) at least three equally spaced parallel vertical lines B1  
direction down B1 [2]
- (ii)  $E = 1500 / 20 \times 10^{-3} = 75000 V m^{-1}$  A1 [1]
- (iii)  $F = qE$  C1  
( $W = mg$  and)  $qE = mg$  C1  
 $q = mg / E = 5 \times 10^{-15} \times 9.81 / 75000$   
 $= 6.5 \times 10^{-19} C$  A1  
negative charge A1 [4]
- (iv)  $F > mg$  or  $F$  now greater B1  
drop will move upwards B1 [2]

#### Q47.

- 5 (a) (i)  $I_1 + I_3 = I_2$  A1 [1]
- (ii)  $E_1 = \frac{I_2 R_2}{2} + \frac{I_1 R_2}{2} + I_1 R_1 + I_1 r_1$  A1 [1]
- (iii)  $E_1 - E_2$  B1  
 $= -I_3 r_2 + I_1 (R_1 + r_1 + R_2 / 2)$  B1 [2]
- (b) p.d. across BJ of wire changes / resistance of BJ changes B1  
there is a difference in p.d across wire and p.d. across cell  $E_2$  B1 [2]

**Q48.**

- 4 (a)** p.d. =  $\frac{\text{energy transformed from electrical to other forms}}{\text{unit charge}}$  B1
- e.m.f. =  $\frac{\text{energy transformed from other forms to electrical}}{\text{unit charge}}$  B1 [2]
- (b) (i)** sum of e.m.f.s (in a closed circuit) = sum of potential differences B1 [1]
- (ii)**  $4.4 - 2.1 = I \times (1.8 + 5.5 + 2.3)$  M1  
 $I = 0.24 \text{ A}$  A1 [2]
- (iii)** arrow (labelled)  $I$  shown anticlockwise A1 [1]
- (iv) 1.**  $V = I \times R = 0.24 \times 5.5 = 1.3(2)\text{V}$  A1 [1]
- 2.**  $V_A = 4.4 - (I \times 2.3) = 3.8(5)\text{V}$  A1 [1]
- 3.** either  $V_B = 2.1 + (I \times 1.8)$  or  $V_B = 3.8 - 1.3 = 2.5(3)\text{V}$  C1  
A1 [2]

**Q49.**

- 2 (a)** resistance = potential difference / current B1 [1]
- (b) (i)** metal wire in series with power supply and ammeter B1  
voltmeter in parallel with metal wire B1  
rheostat in series with power supply or potential divider arrangement or variable power supply B1 [3]
- (ii) 1.** intercept on graph B1 [1]
- 2.** scatter of readings about the best fit line B1 [1]
- (iii)** correction for zero error explained B1  
use of  $V$  and corrected  $I$  values from graph C1  
resistance =  $V / I = 22.(2)\Omega$  [e.g.  $4.0 / 0.18$ ] A1 [3]
- (c)**  $R = 6.8 / 0.64 = 10.625$  C1
- $\%R = \%V + \%I$   
 $= (0.1 / 6.8) \times 100 + (0.01 / 0.64) \times 100$  C1  
 $= 1.47\% + 1.56\%$
- $\Delta R = 0.0303 \times 10.625 = 0.32\Omega$   
 $R = 10.6 \pm 0.3 \Omega$  A1 [3]

**Q50.**

- 5 (a) (i)  $I_1 = I_2 + I_3$  B1 [1]
- (ii)  $I = V / R$  or  $I_2 = 12 / 10$  (= 1.2 A) C1  
 $R = [1/6 + 1 / 10]^{-1}$  [total  $R = 3.75 \Omega$ ] or  $I_3 = 12 / 6$  (= 2.0 A) C1  
 $I_1 = 12 / 3.75 = 3.2 \text{ A}$  or  $I_1 = 1.2 + 2.0 = 3.2 \text{ A}$  A1 [3]
- (iii) power =  $VI$  or  $I^2R$  or  $V^2 / R$  C1
- $x = \frac{\text{power in wire}}{\text{power in series resistors}} = \frac{I_2^2 R_w}{I_3^2 R_s}$  or  $\frac{V_2}{V_3}$  or  $\frac{V^2 / R_w}{V^2 / R_s}$  C1
- $x = 12 \times 1.2 / 12 \times 2.0 = 0.6(0)$  allow 3 / 5 or 3:5 A1 [3]
- (b) p.d. BC:  $12 - 12 \times 0.4 = 7.2 \text{ (V)}$  / p.d. AC = 4.8(V) C1  
p.d. BD:  $12 - 12 \times 4 / 6 = 4.0 \text{ (V)}$  / p.d. AD = 8.0(V) C1  
p.d. = 3.2V A1 [3]

### Q51.

- 4 (a) e.m.f. = chemical energy to electrical energy M1  
p.d. = electrical energy to thermal energy M1  
idea of per unit charge A1 [3]
- (b)  $E = I(R+r)$  or  $I = E / (R+r)$  (any subject) B1 [1]
- (c) (i)  $E = 5.8 \text{ V}$  B1 [1]
- (ii) evidence of gradient calculation or calculation with values from graph  
e.g.  $5.8 = 4 + 1.0 \times r$  C1  
 $r = 1.8 \Omega$  A1 [2]
- (d) (i)  $P = VI$  C1  
 $P = 2.9 \times 1.6 = 4.6$  (4.64)W A1 [2]
- (ii) power from battery =  $1.6 \times 5.8 = 9.28$  or efficiency =  $VI / EI$  C1  
efficiency =  $(4.64 / 9.28) \times 100 = 50 \%$  or  $(2.9 / 5.8) \times 100 = 50\%$  A1 [2]

### Q52.

- 6 (a) p.d. = work (done) / charge OR energy transferred from (electrical to other forms) / (unit) charge B1 [1]
- (b) (i)  $R = \rho l / A$  C1  
 $\rho = 18 \times 10^{-9}$  C1  
 $R = (18 \times 10^{-9} \times 75) / 2.5 \times 10^{-6} = 0.54 \Omega$  A1 [3]
- (ii)  $V = IR$  C1  
 $R = 38 + (2 \times 0.54)$  C1  
 $I = 240 / 39.08 = 6.1$  (6.14) A A1 [3]

(iii)  $P = I^2 R$  or  $P = VI$  and  $V = IR$  or  $P = V^2/R$  and  $V = IR$  C1  
 $= (6.14)^2 \times 2 \times 0.54$  C1  
 $= 41 (40.7) \text{ W}$  A1 [3]

(c) area of wire is less (1/5) hence resistance greater ( $\times 5$ ) M1  
 OR  $R$  is  $\propto 1/A$  therefore  $R$  is greater  
 p.d. across wires greater so power loss in cables increases A1 [2]

**Q53.**

- 6 (a) e.m.f. = total energy available (per unit charge) B1  
 some (of the available energy) is used/lost/wasted/given out in the internal  
 resistance of the battery (hence p.d. available less than e.m.f.) B1 [2]
- (b) (i)  $V = IR$  C1  
 $I = 6.9 / 5.0 = 1.4 (1.38) \text{ A}$  A1 [2]
- (ii)  $r = \text{lost volts} / \text{current}$  C1  
 $= (9 - 6.9) / 1.38 = 1.5(2) \Omega$  A1 [2]
- (c) (i)  $P = EI$  (not  $P = VI$  if only this line given or 9 V not used in second line) C1  
 $= 9 \times 1.38 = 12 (12.4) \text{ W}$  A1 [2]
- (ii) efficiency = output power / total power C1  
 $= VI / EI = 6.9 / 9$  or  $(9.52) / (12.4) = 0.767 / 76.7\%$  A1 [2]

**Q54.**

- 7 (a) (i) six vertical lines from plate to plate equally spaced across plates B1  
 [only allow if greatest to least spacing is  $< 1.3$ , condone slight curving on the  
 two edges. There must be no area between the plates where an additional  
 line(s) could be added.]  
 arrow downwards on at least one line B1 [2]
- (ii)  $E = V/d$  C1  
 $= 1200 / 40 \times 10^{-3} = 3.0 \times 10^4 \text{ Vm}^{-1}$  (allow 1 s.f.) A1 [2]
- (b) (i)  $F = Ee$  C1  
 $= 3 \times 10^4 \times 1.6 \times 10^{-19} = 4.8 \times 10^{-15} \text{ N}$  A1 [2]
- (ii) couple =  $F \times \text{separation of charges}$  C1  
 $= 4.8 \times 10^{-15} \times 15 \times 10^{-3} = 7.2 \times 10^{-17}$  A1  
 unit: N m or unit consistent with unit used for the separation B1 [3]
- (iii) A at top/next to +ve plate B at bottom/next to -ve plate vertically aligned M1  
 [could be shown on the diagram]  
 forces are equal and opposite in same line / no resultant force and no  
 resultant torque A1 [2]







