Q1

5 (a) (i) resistance = V/I C1
= $6.0/(40 \times 10^{-3})$
= 150 Ω A1
(no marks for use of gradient)

(ii) at 8.0 V, resistance = $8.0/(50 \times 10^{-3})$ = 160 Ω C1
change = 10 Ω .... A1 [4]

(b) (i) straight line through origin M1
passes through I = 40 mA, V = 8.0V A1

(ii) current in both must be 40 mA C1
e.m.f. = 8.0 + 6.0 = 14.0 V .... A1 [4]

Q2.

7	**(a)**	**(i)**	$P = VI$	C1	
			current = 60/240 = 0.25 A	A1	
		(ii)	R (= V/I) = 240/0.25	M1	
			= 960 Ω	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 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	B1	**[1]**
			(allow any sensible comment based on candidate's answer for L)		
			Total		**[7]**

Q3.

8	**(a)**	$V/E = R/R_{tot}$	or	$0.5 = I \times 3900$	C1	
		$1.0/1.5 = R/(R + 3900)$	or	$1.0 = 0.5R/3900$	M1	
		$R = 7800\Omega$.	or	$R = 7800\Omega$	A0	**[2]**
	(b)	$V = 1.5 \times (7800/\{7800 + 1250\})$	or	$I = 1.5/(7800 + 1250)$	C1	
		= 1.29 V..	or	$V = IR$ = 1.29 V	A1	**[2]**
	(c)	Combined resistance of R and voltmeter is 3900 Ω			C1	
		reading at 0 °C is 0.75 V			A1	**[2]**
				Total		**[6]**

Q4.

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

Q5.

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

Q6.

7	(a)	lamp C lamp is shorted		M1 A1	[2]
	(b)	shorted <u>lamp A</u> would cause damage to the supply/lamps /blow fuse in supply		B1	[1]
	(c)	15 Ω		B1	[1]
	(d)	(i)	$V = I\,R$ $R = 30\ \Omega$	C1 A1	[2]
		(ii)	$P = VI$ *or* I^2R *or* V^2/R $P = 1.2$ 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 <u>per unit positive</u> charge (on a small test charge)		B1	[1]
	(b)	field strength = $(210/\{1.5 \times 10^{-2}\} =)\ 1.4 \times 10^{4}$ N C^{-1}		A1	[1]
	(c)	(i)	acceleration $= Eq/m$ $= (1.4 \times 10^{4} \times 1.6 \times 10^{-19}) / (9.1 \times 10^{-31})$ $= 2.5 \times 10^{15}$ m s^{-2} (2.46×10^{15}) towards positive plate / upwards (and normal to plate)	C1 C1 A1 B1	[4]
		(ii)	time = 2.4×10^{-9} s	A1	[1]
	(d)	*either* vertical displacement after acceleration for 2.4×10^{-9} s $= \frac{1}{2} \times 2.46 \times 10^{15} \times (2.4 \times 10^{-9})^2$ $= 7.1 \times 10^{-3}$ m (0.71 cm < 0.75 cm and) so will pass between plates *i.e. valid conclusion based on a numerical value*		 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 = 2.47×10^{-9} s (2.4 ns < 2.47 ns) so will pass between plates *i.e. valid conclusion based on a numerical value*		(C1) (A1) (A1)	

Q8.

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

Q9.

6 **(a)** *either* *P* = *VI* and *V* = *IR* *or* $P = V^2 / R$	C1	
resistance = 38.4 Ω	A1	[2]
(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
$= 350 / (2.5 \times 10^{-2})$
$= 1.4 \times 10^{4}$ 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]

(b) (i) $F = ma$ C1
$a = (2.24 \times 10^{-15}) / (9.1 \times 10^{-31})$
$= 2.46 \times 10^{15}$ m s^{-2} …(*allow* 2.5×10^{5}) .... A1 [2]

(ii) $s = ½at^{2}$ C1
$2.5 \times 10^{-2} = ½ \times 2.46 \times 10^{15} \times t^{2}$
$t = 4.5 \times 10^{-9}$ 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 >> 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]

(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)** ∞ A1
$2R$ A1
R .... A1 [3]

(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 × <u>perpendicular</u> distance (between forces) C1

$= 1.6 \times 10^{-19} \times 5.0 \times 10^{4} \times 2.8 \times 10^{-10} \times \sin 30$

$= 1.1 \times 10^{-24}$ N m .... A1 [2]

Q14.

6 **(a)** **(i)** $P = VI$ C1

$60 = 12 \times I$

$I = 5.(0)$ A .... A1 [2]

(ii) *either* $V = IR$ *or* $P = I^2R$ 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

$L = (2.4 \times 5.03 \times 10^{-7})/(1.0 \times 10^{-6})$

$= 1.2$ 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 ± 1 mm …………	B1	[1]
	(ii)	reasonable line/curve through points giving current as 0.12 A *allow ± 0.005A*) …………	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 × R is not equal to current in wire BC × R	B1	[2]
		any 2 statements		

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	M1	
		= 20 Ω	A0	[2]
		(using the gradient loses the last mark)		
	(c) (i)	0.5 A	A1	[1]
	(ii)	*either* resistance of each resistor is 20 Ω *or* total current = 0.8 A	C1	
		either combined resistance = 10 Ω *or* $R = E/I$ = 10 Ω	A1	[2]
	(d) (i)	10 V	A1	[1]
	(ii)	power = EI	C1	
		= 10 × 0.2 = 2.0 W	A1	[2]

Q17.

5	(a)	(i)	$I = 12 / (6 + 12)$	C1	
			minimum current = 0.67 A	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)	$E_B - E_A = I(R + r_B + r_A)$		
			$12 - 3 = I(3.3 + 0.1 + 0.2)$	C1	
			$I = 2.5$ A	A1	[2]
		(ii)	Power $= E \times I$		
			$= 12 \times 2.5$	C1	
			$= 30$ W	A1	[2]
		(iii)	$P = I^2 \times R$ or $P = V^2 / R$ or $P = VI$		
			$= (2.5)^2 \times 3$ $= 9^2 / 3.6$ $= 9 \times 2.5$	C1	
			$= 22.5$ J s^{-1}	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 $V = IR$	C1	
			$R = 144 / 50 = 2.88$ for each lamp	C1	
			total $R = 1.44\ \Omega$	A1	[3]

Q20.

4	(a)	(i)	$R = V^2 / P$ *or* $P = IV$ and $V = IR$	C1	
			$= (220)^2 / 2500$		
			$= 19.4\,\Omega$ (*allow 2 s.f.*)	A1	[2]
		(ii)	$R = \rho l / A$	C1	
			$l = [19.4 \times 2.0 \times 10^{-7}] / 1.1 \times 10^{-6}$	C1	
			$= 3.53\,\text{m}$ (*allow 2 s.f.*)	A1	[3]
	(b)	(i)	$P = 625$, 620 or 630 W	A1	[1]
		(ii)	R needs to be reduced	C1	
			Either length ¼ of original length		
			or area 4× greater		
			or diameter 2× greater	A1	[2]

Q21.

5	(a)	(i)	sum of e.m.f.'s = sum of p.d.'s around a loop/circuit	B1	[1]
		(ii)	energy	B1	[1]
	(b)	(i)	$2.0 = I \times (4.0 + 2.5 + 0.5)$	C1	
			$I = 0.286\,\text{A}$ (*allow 2 s.f.*)	A1	[2]
			(*If total resistance is not 7 Ω, 0/2 marks*)		
		(ii)	$R = [0.90 / 1.0] \times 4$ (= 3.6)	C1	
			$V = I R = 0.286 \times 3.6 = 1.03\,\text{V}$	A1	[2]
			(*If factor of 0.9 not used, then 0/2 marks*)		
		(iii)	$E = 1.03\,\text{V}$	A1	[1]
		(iv)	*either* no current through cell B		
			or p.d. across *r* is zero	B1	[1]

Q22.

4	(a)		total resistance = 20 (kΩ)	C1	
			current = 12 / 20 (mA) or potential divider formula	C1	
			p.d. = [12 / 20] × 12 = 7.2 V	A1	[3]
	(b)		parallel resistance = 3 (kΩ)	C1	
			total resistance 8 + 3 = 11 (kΩ)	C1	
			current = $12 / 11 \times 10^3 = 1.09 \times 10^{-3}$ or 1.1×10^{-3} A	A1	[3]
	(c)	(i)	LDR resistance decreases	M1	
			total resistance (of circuit) is less hence current increases	A1	[2]
		(ii)	resistance across XY is less	M1	
			less proportion of 12 V across XY hence p.d. is less	A1	[2]

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	
			$= 3.2 \times 10^{-19} \times 1200$		
			$= 3.84 \times 10^{-16}$ J	A1	[2]
		(iii)	$\Delta U = mgh$	C1	
			$= 6.6 \times 10^{-27} \times 9.8 \times 14 \times 10^{-3}$		
			$= 9.06 \times 10^{-28}$ J	A1	[2]
		(iv)	$\Delta K = 3.84 \times 10^{-16} - \Delta U$		
			$= 3.84 \times 10^{-16}$ J	A1	[1]
		(v)	$K = ½mv^2$	C1	
			$v = [(2 \times 3.8 \times 10^{-16}) / 6.6 \times 10^{-27}]^{1/2}$		
			$= 3.4 \times 10^5 \text{ m s}^{-1}$	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)	$\Sigma E = \Sigma IR$		
			$20 - 12 = 2.0(0.6 + R)$ *(not used 3 resistors 0/2)*	C1	
			$R = 3.4\,\Omega$	A1	[2]
		(ii)	$P = EI$	C1	
			$= 20 \times 2$		
			$= 40$ W	A1	[2]
		(iii)	$P = I^2R$	C1	
			$P = (2)^2 \times (0.1 + 0.5 + 3.4)$		
			$= 16$ W	A1	[2]
		(iv)	efficiency = useful power / output power	C1	
			24 / 40 = 0.6 or 12 × 2 / 20 × 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 = $I^2R_1 / I^2R_2 = \dfrac{\rho l / \pi d^2}{\rho(2l)/\pi(2d)^2}$ 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 = $3.47 \times 10^7 / 1.6 \times 10^{-19}$ (= 2.17×10^{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. = $\dfrac{\text{work done / energy transformed}}{\text{charge}}$ (from electrical to other forms) B1 [1]

(b) (i) maximum 20 V A1 [1]

(ii) minimum = (600 / 1000) × 20 C1
= 12 V A1 [2]

(c) (i) use of 1.2 kΩ M1
1/1200 + 1/600 = 1/R, R = 400 Ω A1 [2]

(ii) total parallel resistance (R_2 + 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 .... then straight (with no kink at change-over)	B1 B1	[3]
(b)		$E = V/d$ .... $= 400 / (0.8 \times 10^{-2})$ $= 5.0 \times 10^{4}$ V m^{-1} .... (allow 1 sig fig)	C1 A1	[2]
(c) (i)		$F = Eq$ .... $= 5.0 \times 10^{4} \times 1.6 \times 10^{-19}$ $= 8.0 \times 10^{-15}$ N .... (allow 1 sig fig and e.c.f.)	C1 A1	
(ii)		$a = F/m$ .... $= (8.0 \times 10^{-15}) / (9.1 \times 10^{-31})$ $= 8.8. \times 10^{15}$ m s^{-2} ...... (allow 1 sig fig and e.c.f.)	C1 A1	[4]
(d)		because F_E is normal to <u>horizontal</u> motion .... no effect	M1 A1	[2]

Q29.

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

Q30.

5	**(a)**	**(i)**	arrow from B towards A	B1	
		(ii)	*E* = *V*/*d*		
			= 450/(9.0 x 10^{-2})	C1	
			= 5.0 x 10^{3} N C^{-1} (accept 1 sig. fig)	A1	[3]
	(b)	**(i)**	energy = *qV* or *Eqd*	C1	
			= 1.6 x 10^{-19} x 450	A1	
			= 7.2 x 10^{-17} J	A0	
		(ii)	Ek = $\frac{1}{2}mv^2$		
			7.2 x 10^{-17} = ½ x 9.1 x 10^{-31} x v^2	C1	
			v = 1.26 x 10^{7} 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 x *i*	M1	
			i = 5.0 A	A0	
		(ii)	*V* = *iR*		
			240 = 5.0 x *R*	C1	
			R = 48Ω	A1	[4]
	(b)	**(i)**	p.d. = (5.0 x 4.0 =) 20 V	A1	
		(ii)	mains voltage = (240 + 20 =) 260 V	A1	
		(iii)	*P* = (20 x 5.0 =) 100 W	A1	[3]
	(c)		power input = 1200 + 100 = 1300 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 = reciprocal of gradient, then 0/2 marks here)

(ii) current = 2.00 mA C1

resistance = 2 000 Ω A1 [2]

(b) (i) straight line from origin M1

passing through (6.0 V, 4.0 mA) (allow ½ 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)	M1	
			so plate Y is positive	A1	[2]
	(b)	(i)	$E = V / d$	C1	
			$= 630/(0.75 \times 10^{-2})$		
			$= 8.4 \times 10^4$ N C^{-1}	A1	[2]
		(ii)	$qE = mg$	C1	
			$q = (9.6 \times 10^{-15} \times 9.8) / (8.4 \times 10^4)$	C1	
			$= 1.12 \times 10^{-18}$ 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 V	= 2.70 V	A0	[2]
	(b)	(i)	for a wire, $V = I \times (\rho L/A)$		M1	
			I, ρ 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 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.** $E_2 = I_2R_2 + I_3R_3$	B1	[1]
	2. $E_1 - E_2 = I_1R_1 - I_2R_2$	B1	[1]

Q36.

6 (a)	power = VI	C1	
	current = 10.5 × 103 / 230	M1	
	= 45.7 A	A0	[2]
(b) (i)	p.d. across cable = 5.0 V	C1	
	R = 5.0 / 46	C1	
	= 0.11 Ω	A1	[3]
(ii)	$R = \rho L / A$	C1	
	$0.11 = (1.8 \times 10^{-8} \times 16 \times 2) / A$	C1	
	$A = 5.3 \times 10^{-6}$ m^2	A1	[3]
	(wires in parallel, not series, allow max 1/3 marks)		
(c) (i)	*either* power = V^2 / R *or* power ∝ 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 × (V / d) *or* $E = V/d$	C1	
	$= 1.6 \times 10^{-19} \times (250 / 7.6 \times 10^{-3})$	C1	
	$= 5.3 \times 10^{-15}$ N	A1	[3]
(ii)	*either* $\Delta E_K = eV$ *or* $\Delta E_K = Fd$	C1	
	$= 1.6 \times 10^{-19} \times 250$; $= 5.3 \times 10^{-15} \times 7.6 \times 10^{-3}$	M1	
	$= 4.0 \times 10^{-17}$ J	A0	[2]
	(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
$v = 9.4 \times 10^6$ 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)
$v = 9.4 \times 10^6$ m s^{-1} — (A1)

(b) speed depends on (electric) potential difference — M2
(*If states ΔE_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 kΩ resistor / thermistor decreases — M1
p.d. across 2000 Ω 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 kΩ resistor = 1.8 mA — C1
$R = 1.33$ kΩ — current in 5 kΩ resistor = 0.48 mA — C1
$\frac{1}{1.33} = \frac{1}{5} + \frac{1}{T}$ — current in thermistor = 1.32 mA — C1
$T = 1.82$ kΩ — $T = 2.4 / 1.32 = 1.82$ kΩ — 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 Ω ………*(allow ±0.05 Ω)* .... A1 [2]

(ii) current in circuit = $\sqrt{1.4/0.4}$ = 1.87 A C1
1.5 = 1.87 (*r* + 0.40) C1
r = 0.40 Ω ……….. A1 [3]

(d) *either* less power lost / energy wasted / lost
or greater efficiency (of energy transfer) .... B1 [1]

[Total: 11]

Q40.

---

6 **(a)** total resistance in series = 2*R*
total resistance in parallel = ½*R* M1
ratio is 2R / ½R = 4 ......*(allow mark if clear numbers in the ratio)* .... A0 [1]

(b) at 1.5 V, current is 0.10 A C1
resistance = *V*/I = $\frac{1.5}{0.1}$
= 15 Ω .... A1 [2]
(use of tangent or any other current scores no marks)

(c)

	p.d. across each lamp / V	resistance of each lamp / Ω	combined resistance / Ω
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 $V = IR$	C1	
			$R = 4.0\ \Omega$	A1	[2]
		(ii)	sketch vertical axis labelled appropriately	B1	
			(straight) 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 Ω or 1.6 kΩ	C1	
			total resistance = 800 Ω	A1	[2]
		(ii)	*either* use of potential divider formula *or* current = 9 / 2000 (4.5 mA)	C1	
			V = (0.8/2.0) × 9 / V = (9/2000) × 800		
			= 3.6 V / = 3.6 V	A1	[2]
	(b)	(i)	total resistance = 4/5 × 1200	C1	
			= 960 Ω	A1	[2]
		(ii)	for parallel combination, 1/960 = 1/1600 + 1/R_T		
			R_T = 2400 Ω / 2.4 kΩ	C1	
			temperature = 11 °C	A1	[2]
	(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	B1	
			straight and at a tangent to the curve beyond the plates	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	M1	
			provided no external force acts on the system	A1	[2]
			(do not accept 'conserved' but otherwise correct statement gets 1/2)		
		(ii)	(Δp =) 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 Δp 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 × 230) / 1200		
			$R = 230^2 / 1200$ or R = 230 / 5.22	M1	
			= 44.1 Ω = 44.1 Ω	A0	[2]
		(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 Ω	A0	[2]
	(b)		current = 230 /44.6	C1	
			power = $(230 / 44.6)^2 \times 44.1$	C1	
			= 1170 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: $V A^{-1} m^2 m^{-1} = N m C^{-1} A^{-1} m^2 m^{-1}$ — C1

$= kg\,m^2 s^{-2} A^{-1} s^{-1} A^{-1} m^2 m^{-1}$

$= kg\,m^3 s^{-3} A^{-2}$ — A1 [3]

(c) **(i)** $\rho = [3.4 \times 1.3 \times 10^{-7}] / 0.9$ — C1

$= 4.9 \times 10^{-7}$ (Ω m) — A1 [2]

(ii) max = 2.(0) V — A1

min = 2 × (3.4 /1503.4) = 4.5×10^{-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) $E_1 = I_2\dfrac{R_2}{2} + I_1\dfrac{R_2}{2} + I_1R_1 + I_1r_1$ — A1 [1]

(iii) $E_1 - E_2$ — B1

$= -I_3r_2 + I_1(R_1 + r_1 + R_2 / 2)$ — 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

$I = 0.24$ A A1 [2]

(iii) arrow (labelled) I shown anticlockwise A1 [1]

(iv) **1.** $V = I \times R = 0.24 \times 5.5 = 1.3(2)$ V A1 [1]

2. $V_A = 4.4 - (I \times 2.3) = 3.8(5)$ V A1 [1]

3. *either* $V_B = 2.1 + (I \times 1.8)$ *or* $V_B = 3.8 - 1.3$ C1

= 2.5(3) V 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) Ω [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 Ω] or $I_3 = 12 / 6$ (= 2.0 A) — C1
$I_1 = 12 / 3.75 = 3.2$ A or $I_1 = 1.2 + 2.0 = 3.2$ A — A1 [3]

(iii) power = VI or I^2R or V^2 / R — C1

$$x = \frac{\text{power in wire}}{\text{power in series resistors}} = \frac{I_2^2 R_w}{I_3^2 R_s} \text{ or } \frac{VI_2}{VI_3} \text{ or } \frac{V^2/R_w}{V^2/R_s}$$ — 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 × 0.4 = 7.2 (V) / p.d. AC = 4.8 (V) — C1
p.d. BD: 12 – 12 × 4 / 6 = 4.0 (V) / p.d. AD = 8.0 (V) — C1
p.d. = 3.2 V — 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 V — B1 [1]

(ii) evidence of gradient calculation or calculation with values from graph
e.g. 5.8 = 4 + 1.0 × r — C1
r = 1.8 Ω — A1 [2]

(d) **(i)** $P = VI$ — C1
P = 2.9 × 1.6 = 4.6 (4.64) W — A1 [2]

(ii) power from battery = 1.6 × 5.8 = 9.28 or efficiency = VI / EI — C1
efficiency = (4.64 / 9.28) × 100 = 50 % or (2.9 / 5.8) × 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
$R = (18 \times 10^{-9} \times 75) / 2.5 \times 10^{-6} = 0.54$ Ω — 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) $P = I^2R$ or $P = VI$ **and** $V = IR$ or $P = V^2/R$ **and** $V = IR$ C1
$= (6.14)^2 \times 2 \times 0.54$ C1
$= 41\ (40.7)$ W A1 [3]

(c) area of wire is less (1/5) hence resistance greater (×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
$I = 6.9 / 5.0 = 1.4\ (1.38)$ A A1 [2]

(ii) r = lost volts / 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
$= 9 \times 1.38 = 12\ (12.4)$ 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
$= 1200 / 40 \times 10^{-3} = 3.0 \times 10^4\ \text{V m}^{-1}$ (allow 1 s.f.) A1 [2]

(b) (i) $F = Ee$ C1
$= 3 \times 10^4 \times 1.6 \times 10^{-19} = 4.8 \times 10^{-15}$ N A1 [2]

(ii) couple = F × 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]