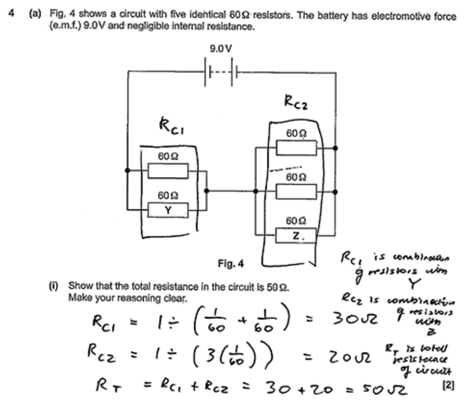
Mark scheme – Energy, Power and Resistance EMF and PD

Question			Answer/Indicative content	Marks	Guidance
1			C	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions. The correct key was **C**. It was only the candidates in the upper quartile who managed to get the correct answer using the expression $Ve = \frac{1}{2}mv^2$ (learning outcome 4.2.2e). Halving the accelerating voltage V will decrease the speed of the electrons by a factor of $\sqrt{2}$.
			Total	**1**	
2			**C**	**1**	
			Total	**1**	
3			**D**	1	
			Total	**1**	
4			D	1	
			Total	**1**	
5			**D**	1	
			Total	**1**	
6			**B**	1	
			Total	**1**	
7			B	1	
			Total	**1**	
8			C	1	
			Total	**1**	
9			C	1	

			Total	**1**	
10			A	1	
			Total	**1**	
11			C	1	
			Total	**1**	
12			B	1	
			Total	**1**	
13			(V_R =) 2.7 (V) **or** (current =) 0.018 (A) (ratio = $\frac{0.018 \times 1.8}{0.018 \times 2.7}$) ratio = 0.67	C1 A1	**Note** the mark can be scored on circuit diagram **Note** values of powers are: 0.0324 W and 0.0486 W **Allow** 2/3; **Not** 0.66 (rounding error)
			Total	**2**	
14			C	1	
			Total	**1**	
15			(1 C =) (1) A s	C1	**Allow** alternative methods
			(1 J =) (1) kg m s^{-2} × m or (1) N = (1) kg m s^{-2}	C1	
			$V = \frac{\text{kg ms}^{-2} \times \text{m}}{\text{As}} = \frac{\text{kgm}^2\text{s}^{-2}}{\text{As}}$ $\text{kg m}^2\text{A}^{-1}\text{s}^{-3}$	M1 A0	**Note** this mark is for clear substitution and working **Examiner's Comments** Some candidates were not clear on what was meant by base units. Most realised that the quantity of electric charge is measured in As. Weaker candidates had difficulty deriving work done.
			Total	**3**	
16	a		(kinetic energy =) 1.6 × 10^{-19} × 300	C1	
			$eV = \frac{1}{2}mv^2$	C1	
			$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 300}{9.11 \times 10^{-31}}}$	C1	**Note** 1.05 × 10^{14} scores 2 marks; omitted square rooting
			speed = 1.03 × 10^7 (m s^{-1})	A0	**Examiner's Comments** Good candidates clearly showed the steps to determine the velocity. Weaker candidates found this question difficult. Clear substitution of numbers is required for these marks to be awarded.

	b		$\lambda = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times1.0\times10^{7}}$	C1	**Allow** ECF from the previous question part
			$\lambda = 7.3 \times 10^{-11}$ (m)	B1	**Allow** 2 marks for 7.1×10^{-11}, $v = 1.03 \times 10^{7}$ used **Examiner's Comments** This part was generally well answered although some candidates confused terms in the equation or could not deal with the powers of ten. Some candidates were confused and used $E=hc/\lambda$.
			Total	**5**	
17			$eV = ½mv^2$ so $v^2 = 2eV/m$ $ma = eE$ so $a = eE/m$ $x = vt$ $d = ½at^2 = ½a(x/v)^2$ $d = (eE/2m).x^2.(m/2eV) = Ex^2/4V$ $x^2 = 4(d/E)V$	B1 B1 B1 B1 B1 A0	four equations are needed and some sensible substitution, etc. shown for the fifth mark
			Total	**5**	
18	a		E = y-intercept r = - gradient	B1 B1	E must be the subject R must be the subject **Do not accept** gradient = - r
	b	i	$\left(R = \frac{5.68}{0.025} =\right) 230\ \Omega$	A1	**Allow** 227
		ii	$\left(\frac{5.68^2}{\textbf{(c)(i)}} \text{ or } 0.025^2 \times \textbf{(c)(i)} \text{ or } 0.025 \times 5.68 =\right) 0.14$ 0.14 × 300 = 42 (J)	C1 A1	**Allow** ECF from (c) **(i)** 0.140 or 0.142 or 0.144 **Allow** 43 (J) (for 0.142 or 0.144)
		iii	$\left(Q = \frac{\text{(c)(ii)}}{5.68} \text{ or } 0.025 \times 300 =\right) 7.4$ or 7.5 C	B1 B1	**Allow** ECF from (c) **(ii)**
			Total	**7**	
19		i	Similarity – same unit (AW)	B1	**Allow** 'both defined as energy (transformed) per unit charge' or 'both defined as work done per unit charge'
		i	Difference – For e.m.f, energy is transformed from chemical / other forms to electrical and for p.d., energy is transformed to heat / other forms from electrical	B1	**Allow** any pair from: e.m.f.: Energy (transformed) to electrical — p.d.: Energy (transformed) from electrical or Energy (transformed) to heat /other forms e.m.f.: Charges gain energy — p.d.: Charges lose energy

					<table><tr><td>Work done on charges</td><td>Work done by charges</td></tr></table> **Examiner's Comments** Most candidates knew that e.m.f. and p.d. were both measured in volts (V). A small number of candidates thought that '*volt*' was the same as '*voltage*'. This question benefitted those who taken time to revise thoroughly. The modal mark was one, but a significant number of candidates scored two marks for their flawless answers.
		ii	$n = \frac{9.6\times10^{16}}{1.2\times10^{-6}\times6.0\times10^{-3}}$ or $n = 1.3(3...)\times10^{25}$ (m^{-3}) (*I = Anev)*	C1	
		ii	$0.003 = 1.2 \times 10^{-6} \times 1.33... \times 10^{25} \times 1.6 \times 10^{-19} \times v$	C1	**Note** Any subject for this equation
		ii	$v = 1.2 \times 10^{-3}$ ($m\ s^{-1}$)	A1	**Allow** 1 mark for $1.6(3) \times 10^5$ ($m\ s^{-1}$); $n = 9.6 \times 10^{16}$ used **Examiner's Comments** Almost all candidates were familiar with the equation $I = Anev$. However, only the top-end candidates realised that the number density of the charge carriers (electrons) had to be calculated from the number of electrons given and the volume of the resistor. The majority of candidates incorrectly assumed n to be 9.6×10^{16} m^{-3} when it should have been 1.3×10^{25} m^{-3}. Examiners awarded one mark for those candidates who arrived at the answer 1.6×10^5 $m\ s^{-1}$ using the incorrect value of n.
			Total	**5**	
20		i	Electrons behave **or** travel as waves.	B1	
		i	The rings demonstrate that the electrons are diffracted by individual carbon atoms / spacing between carbon atoms.	B1	
		i	The (de Broglie) wavelength of the electrons is comparable to the 'size' of the carbon atoms or the spacing between carbon atoms.	B1	
		ii	$v^2 = \frac{1.6\times10^{-19}\times1200}{0.5\times9.11\times10^{-31}}$ or $v = 2.053.. \times 10^7$ ($m\ s^{-1}$)	C1	Correct use of ½ $mv^2 = eV$
		ii	$\lambda = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times2.053\times10^7}$	C1	
		ii	wavelength = 3.5×10^{-11} (m)		

		iii	Results published to allow peer review Procedure shared with other scientists to allow replication	B1	
			Total	**6**	
21		i	$V = \frac{1.1}{6.8 + 1.4 + 1.1} \times 6$ 0. 71 (V)	**C1** **A1**	**Allow** $I = \frac{6}{(6.8+1.4+1.1)\times10^3} = 0.00065$ **Allow** 0.7 **Examiner's Comments** Candidates who use the potential divider equation invariably gained the correct answer of 0.71 V. Alternatively, some candidates correctly determined the current and then determined the voltmeter reading.
		ii	As temperature of thermistor increases, resistance of thermistor decreases Total resistance of circuit decreases or current increases Greater proportion of p.d. across <u>fixed resistor</u> or p.d. across <u>fixed resistor</u> increase Reading on the voltmeter will increase	**B1** **B1** **M1** **A1**	**Examiner's Comments** Candidates were expected to explain how the voltmeter reading would change as the temperature of the thermistor increased. Good answers used a step-by-step approach. Candidates needed to explain how the potential difference of across the fixed resistor would change. It was essential that clearly defined terms were used – often candidates referred to V_1, R_2, or p.d. and resistance without indicating explicitly the meaning of V_1, R_2, or explaining which p.d. or resistance was being referred to.
			Total	**6**	
22	a	i	$\frac{1}{R} = \frac{1}{60} + \frac{1}{60}$ or $\frac{1}{R} = \frac{1}{60} + \frac{1}{60} + \frac{1}{60}$ or $R = \frac{60}{n}$ or $R = \frac{60\times60}{60+60}$ 30 Ω + 20 Ω = 50 Ω	M1 A1	<u>**Examiner's Comments**</u> This question was generally answered well although, a number of candidates did not take due care when writing the mathematical expressions. **Exemplar 6**  The candidate's response is logically

					structured showing the effective resistance of the two combinations of resistors and then clearly showing the adding of the two effective resistances together. This answer gained both marks.
		ii	$\frac{30}{50} \times 9$ or $I = \frac{9}{50} = 0.18$ A 5.4 V	C1 A1	**Examiner's Comments** For this question, many candidates incorrectly stated that the potential difference was 4.5 V. Other candidates tried determining the current but did not make clear their working. The simplest solution was to use the potential divider relationship.
		iii	$\left(I = \frac{5.4}{60} =\right)$ 0.090 A (0.09 x 120 =) 11 C or coulomb	C1 A1 B1	**Allow ECF** from **(ii)** **Allow** 10.8 **Note** 0.18 C scores two marks provided 0.09 A is seen **Note** 21.6 C scores one mark (for the correct unit) **Examiner's Comments** The majority of the candidates gained a mark for the unit of charge on this question. A common incorrect answer was 21.6 C where candidates had used the total current in the circuit rather than the current of 0.09 A in resistor Y. Some candidates did not change the time in minutes to a time in seconds.
		iv	(11 x 5.4 or 0.09 x 5.4 x 120)= 59 or 58 (J)	A1	**Note** 58(.3) if 10.8 C used **Allow ECF** from **(ii)** and/or **(iii)** **Not** 60 **Examiner's Comments** Candidates who multiplied the charge by the potential difference easily gained the mark in this question. Other candidates who used different methods often made mistakes.
	b		I = *nAve* or *v α I* larger current through **Y** than **Z** ORA	B1 B1	**Allow** any correct rearrangement of *I* = *nAve* **Allow** I_Y = 0.090 A <u>and</u> I_Z = 0.060 A OR I_Y / I_Z = 1.5 ORA

			drift velocity in **Y** is 1.5 times drift velocity in **Z** ORA	B1	**Examiner's Comments** In this question, many candidates correctly quoted the equation and stated that the mean drift velocity was directly proportional to the current. The majority of the candidates realised that there was a larger current in resistor Y than resistor Z; however, few candidates realised that the current was 1.5 times larger and therefore the mean drift velocity was 1.5 times larger.
			Total	**11**	
23		i	$Vq = ½ mv^2$ **and** $\lambda = \frac{h}{mv}$ Clear algebra leading to $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$	M1 A1	**Allow** *p* for *mv* **Allow** *e* for *q* in **(b)(i)** – this is to be treated as a 'slip'
		ii	**1** (% uncertainty in λ^2 =) 10% (% uncertainty in λ =) 5% **2** Straight line of best fit passes through all error bars gradient = 1.0 (× 10^{-22}) **3** $\frac{h^2}{2mq} =$ gradient $\frac{(6.63\times10^{-34})^2}{2\times m\times3.2\times10^{-19}} =$ gradient $m = 6.9 \times 10^{-27}$ (kg) (hence about 10^{-26} kg)	C1 A1 B1 C1 C1 C1 A1	**Note** 10 (%) on answer line will score the C1 mark **Ignore** POT for this mark; **Allow** ± 0.20 (× 10^{-22}) Possible ECF for incorrect value of gradient **Note check for AE** (condone rounding error here) **and** answer must be about 10^{-26} (kg) for any incorrect gradient value for this A1 mark **Special case**: 1.37×10^{-26} kg scores 3 marks for $q = 1.6 \times 10^{-19}$ C because answer is about 10^{-26} kg
			Total	**9**	