1	(a)	Any **two** from: Travel through a vacuum (NOT travel through 'space', but allow *free space*) Travel at the speed of light / 3.0×10^8 (ms^{-1}) (in vacuum) They consist of photons Consist of oscillating electric and magnetic fields They are transverse wave / They can be polarised They can be diffracted / reflected / refracted / interfered (-1 for each contradictory statement)	B1x2
	(b)	$v = f\lambda$ / $c = f\lambda$ (Wave equation with any subject) $\lambda = 3.0 \times 10^8 / 1.8 \times 10^9$ $\lambda = 0.168 = 0.17$ (m)	C1 C1 A1
	(c)	Wavelength in the range: 10^{-8} to 10^{-12} (m) (Allow upper limit of 10^{-11} (m) for the wavelength)	B1
			[Total 6]
2	(a)	Arrow (within the lemon and) towards the negative terminal	B1
	(b)(i)	$\Delta Q = I\Delta t$ (Allow other subject. 't' is not necessary) charge = $1.2 \times 10^{-3} \times 6.9 \times 10^5$ charge = 828 ≈ 830 (C) (-1 for 10^3 error and -1 for t = 8 days)	C1 C1 A1
	(ii)	$P = VI$ $P = 1.32 \times 1.2 \times 10^{-3}$ (ECF for current from b(i)) $P = 1.58 \times 10^{-3} = 1.6 \times 10^{-3}$ unit: W / Js^{-1} / VA	C1 A1 B1
			[Total 7]
3	(a)	$R = \frac{R_1 R_2}{R_1 + R_2}$ / $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ / $R = \frac{180 \times 120}{180 + 120}$ / $\frac{1}{R} = \frac{1}{120} + \frac{1}{180}$	C1
		$R = 72$ (Ω) (-1 for each error)	A1
		$R_{xy} = 72 + 100 = 172$ (Ω) (Allow 170) (Possible ECF)	A1
	(b)	Any **four** marks from: Resistance of thermistor decreases as temperature increases (ora) B2 (Resistance of circuit changes with temperature scores 1 mark) The voltmeter reading / voltage stays constant / at 4.5 (V) (AW) B1 The ammeter reading / current increases B1 The current is inversely proportional to the resistance of the thermistor B1 One mark for QWC (Spelling and grammar) B1	
			[Total 8]

4 **(a)** $V = 0.014 \times 160$ **M1**
$V = 2.24\ V \approx 2.2\ V$ **A0**

(b) $V = 12 - 2.24$
$V = 9.76\ (V) \approx 9.8\ (V)$ **B1**

(c)(i) area $= \pi \times (4.0 \times 10^{-2})^2$ / area $= \pi \times 4.0^2 / 10^2$ **M1**
area $= 5.03 \times 10^{-3}\ (m^2) \approx 5.0 \times 10^{-3}\ (m^2)$ **A0**

(ii) $R = \rho l / A$ (Allow any subject) **C1**
$R = 1.7 \times 10^{-8} \times 0.85 / 5.0 \times 10^{-3}$ **C1**
$R = 2.9 \times 10^{-4}\ (\Omega)$ (1 if $5.0 \times 10^{-3}\ (m^2)$ is not used from c(i)) **A1**

(iii) The resistance decreases by a factor of eight **M1**
because area increases by a factor of four and length decreases **A1**
$(3.6 \times 10^{-5}\ (\Omega)$ with correct working scores 2/2)
$(3.6 \times 10^{-5}\ (\Omega)$ without working scores 1/2)
(Allow 1/2 for 'Resistance decreases by a factor of four because length decreases and area increases by a factor of two scores')

[Total 8]

5 A correct potential divider circuit with LDR, voltmeter (variable) resistor and cell (allow a battery) **B1**
Correct symbols for LDR, cell (allow battery), variable resistor and voltmeter **B1**
(-1 for an error or omission)

Any **five** from: (These must be stated and not from the diagram)

The (variable) resistor and LDR are connected in series (to the cell) **B1**
The voltmeter is placed across (variable) resistor / LDR **B1**
$V = \dfrac{R_2 V}{R_1 + R_2}$ / $\dfrac{V_1}{V} = \dfrac{R_1}{R}$ quoted **B1**
The resistance of LDR decreases as intensity of light increases (AW) **B1**
Correct description of how voltage/voltmeter reading changes with light intensity **B1**
The change in voltage / voltmeter reading is justified in terms of potential divider / ratio of resistance values / $I = V/(R_1 + R_2)$ and $V = IR_2$ **B1**
Correct description of how the (circuit) current is affected by intensity **B1**

The variable resistor is used for 'sensitivity' / determining 'range' / 'calibration' / (monitor) different light levels **B1**

One mark for QWC (Organisation) **B1**

[Total 9]

6	(a)(i)	Into (plane of) paper	B1
	(ii)	Correct region to the left of the conductor	B1
	(b)	$F = BIL$ (Allow any subject) $B = 3.0 \times 10^{-1} / (0.2 \times 0.027)$ $B = 5.56 \times 10^{0} \approx 5.6 \times 10^{0}$ units: tesla / T / $NA^{-1}m^{-1}$ / Wbm^{-2}	C1 A1 B1
			[Total 5]
7	(a)	(1 eV) is the work (done) / energy gained / transformed by an electron travelling / accelerated through / across a p.d. / voltage of 1 V (Allow a proton instead of an electron) 1 eV = 1.6×10^{-19} (J) (Ignore omission of unit but NOT 1.6×10^{-19} C)	B1 B1
	(b)	energy, photon and (photo)electron respectively	B1 × 3
		(Allow 'momentum' / 'charge' instead of 'energy' for the first marking point)	
	(c)(i)	energy of photon = work function energy + KE / $hf = \phi$ + KE $\phi = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 3.2 \times 10^{-7}$ / $\phi = 6.63 \times 10^{-34} \times 9.375 \times 10^{14}$ $\phi = 6.22 \times 10^{-19}$ (J) $\approx 6.2 \times 10^{-19}$ (J) $\phi = 6.22 \times 10^{-19} / 1.6 \times 10^{-19}$ $\phi = 3.88$ (eV) ≈ 3.9 eV Poss b.e. ECF	B1 C1 A1 A1
	(ii)	No (photo)electrons Photon energy is less than the work function (energy) / The frequency (of the radiation) is less than the threshold frequency / Photons repel the metal	B1 B1
			[Total 11]
8	(a)	$\lambda = \frac{h}{mv}$ / $\lambda = \frac{h}{p}$ λ = wavelength, h = Planck constant. m = mass (of particle) and v = speed / velocity OR p = momentum	M1 A1
	(b)(i)	Neutrons have no charge / Neutrons experiences no electrical forces (cra)	B1
	(ii)	$2.6 \times 10^{-15} = 6.63 \times 10^{-34} / mv$ / $mv = 2.55 \times 10^{-19}$ (kgms^{-1}) $v = 6.63 \times 10^{-34} / (2.6 \times 10^{-15} \times 1.7 \times 10^{-27})$ / $v = 2.55 \times 10^{-19} / 1.7 \times 10^{-27}$ $v = 1.5 \times 10^{8}$ (ms^{-1}) (Allow use of $m_n = 1.67 \times 10^{-27}$ kg)	C1 C1 A1
			[Total 6]