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 **B1x2**
(-1 for each contradictory statement)

(b) $v = f\lambda$ / $c = f\lambda$ (Wave equation with any subject) **C1**
$\lambda = 3.0 \times 10^8 / 1.6 \times 10^9$ **C1**
$\lambda = 0.188 \approx 0.19$ (m) **A1**

(c) Wavelength in the range: 10^{-16} to 10^{-12} (m) **B1**
(Allow upper limit of 10^{-11} (m) for the wavelength)

[Total 6]

2 (a) Arrow (within the lemon and) towards the negative terminal **B1**

(b)(i) $\Delta Q = I\Delta t$ (Allow other subject. Δ is not necessary) **C1**
charge = $1.2 \times 10^{-3} \times 6.9 \times 10^5$ **C1**
charge = $828 \approx 830$ (C) (-1 for 10^n error and -1 for t = 8 days) **A1**

(ii) $P = VI$ **C1**
$P = 1.32 \times 1.2 \times 10^{-3}$ (ECF for current from b(i))
$P = 1.58 \times 10^{-3} \approx 1.6 \times 10^{-3}$ **A1**
unit: W / Js^{-1} / VA **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 $= \pi \times (4.0 \times 10^{-3})^2$ / area $= \pi \times 4.0^2/10^6$ **M1**
area $= 5.03 \times 10^{-5}\ (m^2) \approx 5.0 \times 10^{-5}\ (m^2)$ **A0**

(ii) $R = \rho L/A$ (Allow any subject) **C1**
$R = 1.7 \times 10^{-8} \times 0.85 / 5.0 \times 10^{-5}$ **C1**
$R = 2.9 \times 10^{-4}\ (\Omega)$ (-1 if $5.0 \times 10^{-5}\ (m^2)$ 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**
$V = \frac{R_2 V_0}{R_1 + R_2}$ / $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ 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) **C1**
$B = 3.0 \times 10^{-6} / (0.2 \times 0.027)$
$B = 5.56 \times 10^{-4} \approx 5.6 \times 10^{-4}$ **A1**
unit: tesla / T / $NA^{-1}m^{-1}$ / Wb m^{-2} **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 **B1**
(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**

(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 / $hf = \phi$ **B1**
$\phi = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 3.2 \times 10^{-7}$ / $\phi = 6.63 \times 10^{-34} \times 9.375 \times 10^{14}$ **C1**
$\phi = 6.22 \times 10^{-19}$ (J) $\approx 6.2 \times 10^{-19}$ (J) **A1**

$\phi = 6.22 \times 10^{-19} / 1.6 \times 10^{-19}$
$\phi = 3.88$ (eV) ≈ 3.9 eV Possible ECF **A1**

(ii) No (photo)electrons **B1**
Photon energy is less than the work function (energy) / The frequency (of the radiation) is less than the threshold frequency / Photons heat the metal **B1**

[Total 11]

8 **(a)** $\lambda = \frac{h}{mv}$ / $\lambda = \frac{h}{p}$ **M1**
λ = wavelength , h = Planck constant,
m = mass (of particle) and v = speed / velocity OR p = momentum **A1**

(b)(i) Neutrons have no charge / Neutrons experiences no electrical forces (ora) **B1**

(ii) $2.6 \times 10^{-10} = 6.63 \times 10^{-34} / mv$ / $mv = 2.55 \times 10^{-24}$ ($kgms^{-1}$) **C1**
$v = 6.63 \times 10^{-34} / (2.6 \times 10^{-10} \times 1.7 \times 10^{-27})$ / $v = 2.55 \times 10^{-24} / 1.7 \times 10^{-27}$ **C1**
$v = 1.5 \times 10^{3}$ (ms^{-1}) (Allow use of $m_n = 1.67 \times 10^{-27}$ kg) **A1**

[Total 6]