1

(a)(i) Electron B1

(ii) Ion B1

(b) Voltage / p.d. B1
Current B1
(R = V/I scores 1/2 if symbols are not defined)
(Symbols 'V' and 'I' alone score 0/2)

(c)(i) $I = \Delta Q/\Delta t$ (Allow other variants - Δ not essential) C1
$I = 650 / 1.6 \times 10^{7}$ C1
$I = 4.0(6) \times 10^{-5}$ (A) A1

(ii) $R = 1.3/4.0(6) \times 10^{-5}$ C1
$R = 3.2(0) \times 10^{4}$ (Ω) (Possible e.c.f) A1

(iii) number $= 650/1.6 \times 10^{-19}$ C1
number $= 4.0(6) \times 10^{21}$ A1

[Total: 11]

2

(a) Conductor: Straight line through origin B1
Lamp: Correct curve, with graph passing through origin B1
Diode: $I \approx 0$ (or small and negative) for $V < 0$ (/ 0.6 V / 0.2 V)
and correct 'shape' for $V > 0$ (/ 0.6 V / 0.2 V) B1

(b) Conductor: Constant R. B1
Idea of $I \propto V$ / I/V = constant. B1

Lamp: R increases as V / I increases B1
(R increases because) temperature increases / Lamp/filament gets hot(ter) *(Do not allow answers in terms of 'heat')* B1

Diode: No conduction: R infinite / (very) large B1
Conduction: R small / decreases as V increases B1

One further point from: B1
Metal conductor is ohmic / filament lamp is not ohmic / diode is not ohmic
Change in lamp's resistance explained in terms of 'mobility of electrons'
Switch-on p.d identified for diode

[Total: 10]

3

(a) (NTC) Thermistor B1

Resistance decreases (as temperature is increased) (wtte) B1

(b)(i)

$V = V_0 \times R_2 / R_1 + R_2$

$V = 9.0 \times 4.2 / (4.2 + 1.2)$

$V = 7.0$ (V) *(Allow 7 (V)*

OR

$V = IR$ and $R = R_1 + R_2$ C1

$I = 9.0 / 5400 = 1.67 \times 10^{-3}$ (A) C1

$V = 1.67 \times 10^{-3} \times 4200$

$V = 7.0$ (V) *(Allow 7 (V)* A1

(If R = 4200Ω or 1200 Ω used to find circuit current, then 0/3)

(Answer of 2.0 (V) scores 2/3)

(ii) Decreases (The answer must be consistent with type of thermistor in **(a)**) B1

[Total: 6]

4

(a) $\rho = RA / L$ (Allow $R = \rho l/A$) M1

Symbols defined:

(ρ = resistivity) A = cross-sectional area, R = resistance and L = length A1

(resistivity = product of resistance and cross sectional area per (unit) length scores 2/2)

(resistivity = product of resistance and cross sectional area per (unit) metre scores 1/2)

(b)(i) $h = 1.2 \times 10^{-5} / 3.0 \times 10^{-4}$ C1

$h = 4.0 \times 10^{-2}$ (m) A0

(ii) $R = \rho l/A$

$R = 6.9 \times 10^{-2} \times 4.0 \times 10^{-2} / 3.0 \times 10^{-4}$ (-1 for 10^n error) C1

$R = 9.2(0)$ (Ω) A1

(R = 920 (Ω) scores 1/2)

(c) Resistance decreases M1

by a factor of four because the length is halved (and area is doubled) A1

(Numerical approach with R = 2.3 (Ω) scores 2/2)

[Total: 7]

5

(a)(i) Parallel B1

(ii) $R = R_1R_2 / R_1 + R_2$ / $1/R_T = 1/R_1 + 1/R_2$ C1
$R = 1.5 \times 1.0 / (1.5 + 1.0)$ / $R = 1/1.67$ / $1/R = 1.67$ C1
$R = 0.6\ (\Omega)$ A0

(b)(i) e.m.f. is the (total) energy (gained) / work done per (unit) charge B1
Energy transformed into electrical / gained by charges B1
OR
$E = W/Q$ M1
(E = e.m.f) W = energy gained / converted to electrical and Q = charge A1

(ii) The chemicals (within the cell) B1

(iii) $R = R_1 + R_2$ / $R = 0.8 + 0.6$ C1
$R = 1.4\ (\Omega)$ A1

(iv) $I = 1.5 / 1.4$ C1
$I = 1.0(7)$ (A) (Possible e.c.f) A1

(v) **1.** $P = VI$ / I^2R / V^2/R B1

2. $P_{int} = 1.0(7)^2 \times 0.8 = (0.916\ W)$ / $P_{ext} = 1.0(7)^2 \times 0.6 = (0.687\ W)$ C1
ratio = 0.8 / 0.6 / ratio = 0.916/0.687 C1
ratio = 1.3(3) A1
(ratio = 0.6/0.8 = 0.75 scores 2/3)
(ratio = 0.571, when R = 1.4Ω is used instead of 0.6Ω, scores 2/3)
(ratio = (1.07 × 0.8) / (1.07 × 0.6) scores 0/3)

[Total: 14]

6

(a) The wire is surrounded by magnetic field *(Do not allow E.M field)* B1

(b) Concentric circles round wire (Judged by eye) (Minimum of 2 circles) M1
Increasing separation between successive circles (Minimum of 3 circles) A1
Correct direction of field (anticlockwise) B1

(c) *F*: force (on conductor) B1
I: current (in conductor) B1
l: length (of conductor) in field B1

(d)(i) Rod moves to the right / towards the battery B1
(Fleming's) left hand (rule) B1

(ii) $F = 1.8 \times 10^{-3} \times 2.0 \times 5.0 \times 10^{-2}$ C1
$F = 1.8 \times 10^{-4}$ (-1 for 10^n error) A1
unit : newton / N (do not allow n) B1
($F = 1.8 \times 10^{-2}$ N scores 2/3)

[Total: 12]

7

(a) Any two from: B1 × 2
Travel at the speed of light / 3×10^8 (ms^{-1}) (in vacuum)
Can travel in a vacuum / space
Transverse waves / Can be polarised
Consist of oscillating electric and magnetic fields
May be diffracted / reflected / refracted etc.

(b)(i) Quantum of energy / radiation
OR 'packet' / 'bundle' / 'lump' of energy B1
(Do not allow 'E =hf' here)

(ii) $E = 1.0 \times 10^6 \times 1.6 \times 10^{-19}$
use of 10^6 factor in answer C1
use of $1eV = 1.6 \times 10^{-19}$ (J) in answer C1
$E = 1.6 \times 10^{-13}$ (J) A0

(iii) $E = hf$ (Allow this if given in **(b)(i)**) (Allow other variants) C1
$f = 1.6 \times 10^{-13} / 6.63 \times 10^{-34}$ C1
$f = 2.4(1) \times 10^{20}$ A1
unit: hertz / Hz (Allow hz / HZ - as BOD) B1

(iv) $\lambda = 3.0 \times 10^8 / 2.4(1) \times 10^{20}$ C1
$\lambda = 1.2(4) \times 10^{-12}$ (m) (Possible e.c.f) A1

(v) Principal radiation: γ-rays / radiation. B1

[Total: 12]

8

(a) Photoelectric (effect) B1

(b) Charge on plate becomes (more) positive (with time) B1
Negative charge(s) / electrons leave the plate B1

(c) More / greater (rate of emission of) electrons B1
More / greater (rate of arrival of) photons B1

(d) Minimum energy needed to remove / emit / escape / release / lift electron
(from metal surface) B1

[Total: 6]

9 Any eight from:

Wave behaviour.....

Electrons travels / propagates / moves (in space) like a wave	B1
Electrons shows diffraction / interference (effects)	B1
Electrons may be diffracted by matter (graphite, carbon etc.) / atoms / nuclei	B1
Experimental evidence: 'rings / fringes'	B1
Diffraction of electrons when λ is comparable to 'gap size'	B1
(Wavelength given by de Broglie equation) $\lambda = h/p$ or $\lambda = h/mv$	M1
Symbols defined: p = momentum , m = mass and v = speed or velocity and λ = (de Broglie) wavelength	A1

Particle-behaviour.....

'Interacts' (with matter) like a particle	B1
Electrons has mass	B1
Electrons have charge	B1
Electrons may be deflected by electric field / charges	B1
Electrons may be deflected by magnetic field	B1
Newtonian mechanics may be applied to it / Can use 'F = ma'	B1

[Total: 8]

QWC applied to Q2b & Q9
Maximum of **4 marks** - see criteria