

1. (a)(i) Coulomb / C (Allow Ampere second / As) B1
- (ii) Voltmeter B1
- (b)(i) $P = VI$ (Allow other variant) C1
 $V = 36 / 3.0$ C1
 p.d. = 12 (V) A1
- (ii) $E = 36 \times 600$ C1
 energy = $2.1(6) \times 10^4$ (J) $\approx 2.2 \times 10^4$ (J) A1
- (iii) $\Delta Q = I\Delta t / Q = It$ (Allow other variant) C1
 $\Delta Q = 3.0 \times 600$ C1
 charge = 1.8×10^3 (C) A1
- (iv) $N = 1.8 \times 10^3 / 1.6 \times 10^{-19}$ (Possible ECF) C1
 number = $1.1(3) \times 10^{22} \approx 1.1 \times 10^{22}$ A1
- [Total: 12]
2. (a) $R = V / I$ M1
 Symbols defined: R = resistance, V = p.d. and I = current A1
 (Allow use of 'voltage' instead of 'p.d.')
- (Resistance = p.d. per (unit) current scores 2/2)
 ($V = IR$ with all symbols defined scores 1/2)
 (Resistance = p.d. per (unit) amp / A scores 1/2)
 (Resistance = volts per (unit) current scores 1/2)
 (Resistance = volts per (unit) ampere scores 0/2)
- (b)(i) $I \propto V / l \div V = \text{constant}$ C1
 Current \propto p.d. / p.d. \div current = constant and (metallic conductor at) A1
 constant temperature
 (Allow symbols in (b)(i) if defined in (a))
- (ii) One correct response scores 1/2
 Three correct responses scores 2/2
- (c) Ammeter in series B1
 Voltmeter across cell or the thermistor B1
 (No credit if the meters or their positions are contradictory)

[Total: 8]

3. (a)(i) $R = 50 \Omega$ C1
 $I = 3.0 / 50$ C1
current = 0.06 (A) A1
- (ii) $P = VI / V^2 / R / I^2 R$ C1
power = 3.0×0.06
power = 0.18 (W) (Possible ECF) A1
- (b)(i) 'Constant' temperature implied (wtte) B1
(Do not allow reference to Ohm's law or to 'heating')
- (ii) 1. 40 (Ω) B1
2. $A = \pi \times (1.0 \times 10^{-5})^2 = 3.1(4) \times 10^{-10} \text{ (m}^2\text{)}$ B1
 $R = \rho L/A$ (Allow other variant) C1
 $40 = 5.4 \times 10^{-8} \times L / 3.1(4) \times 10^{-10}$ (Possible ECF) C1
 $L = 0.23(3) \text{ (m)} \approx 0.23 \text{ (m)}$ A1
Length is 9too) long, therefore must be coiled (wtte) B1

[Total: 12]

4. (a)(i) p.d.: Energy 'lost' by charge(s)/ electron(s) (as heat / light) B1
e.m.f: Energy 'gained' by charge(s)/ electron(s) (as electrical) B1
(p.d. linked to energy transfer to heat/light and e.m.f to energy transfer to electrical scores 1/2)
- (ii) Tick only for $J C^{-1}$ B1
- (b) (Sum of) e.m.f.s = sum / total of p.d.s / sum of voltages (in a loop) B1
(Do not allow equation unless the symbols are defined)
Energy is conserved B1
- (c)(i) $R = 1.28 / 0.80$ C1
resistance = 1.6(0) (Ω) A1
- (ii) $R = R_1 + R_2 / 1.60 = r + 1.10 / r = (1.28 - 0.8 \times 1.1) / 0.8$ C1
 $r = 0.5(0) \text{ (}\Omega\text{)} \approx 0.5 \text{ (}\Omega\text{)}$ (Possible ECF) A1
- (iii) p.d = $1.10 \times 0.80 = 0.88 \text{ (V)}$ (Possible ECF) B1

[Total: 10]

5. (a)(i) Decreases B1
- (ii) Decreases B1
- (b)(i) $V = V_0 \times R_2 / R_1 + R_2$ | $V = IR$ and $R = R_1 + R_2$ C1
 $V = 5.0 \times 420 / (1000 + 420)$ | $I = 5.0 / 1420 = 3.52 \times 10^{-3} \text{ (A)}$ C1
 p.d. = 1.4(*) (V) \approx 1.5 (V) | p.d. = $3.52 \times 10^{-3} \times 420 \approx 1.5 \text{ (V)}$ A1
 (Answer of 3.5(2) (V) scores 2/3)
- (ii) 1. $R = R_1 R_2 / R_1 + R_2 = 420 \times 50 / 420 + 50 (=44.7 \text{ } (\Omega))$ B1
2. $V = 5.0 \times 45 / (1000 + 45)$ | $I = 5.0 / 1045 = 4.78(5) \times 10^{-3} \text{ (A)}$ C1
 p.d. = 0.21(5) (V) \approx 0.22 (V) | p.d. = $4.78 \times 10^{-3} \times 420 \approx 0.22 \text{ (V)}$ A1
 (Allow $V \approx 0.2 \text{ (V)}$ as long as working is shown)
- [Total: 8]
6. (a)(i) Correct direction of field (clockwise) B1
 Concentric circles round wire (Judge by eye) M1
 Increasing separation between successive circles (\geq three lines) A1
- (ii) 1. (Fleming's) Left hand rule B1
2. To the left / Towards the other wire (No ECF from (a)(i)) B1
 Can score on Fig.6.1
- (b)(i) $B = F / IL$ M1
 $F =$ force, $I =$ current and $L =$ length of conductor / wire (in the field) A1
 (B = force per (unit) current length of conductor scores 2/2)
 (F = BIL with symbols defined scores 1/2)
 (B = force per (unit) ampere metre scores 1/2)
 (B = force when current is 1A and length is 1m scores 0/2)
- The conductor / wire normal to field A1
- (ii) $F = 2.5 \times 10^{-5} \times 3.0 \times 2.0$ C1
 force = $1.5 \times 10^{-4} \text{ (N)}$ A1

[Total: 10]

7. (a) hf: Photon energy / quantum of energy B1
 ϕ : Work function (energy for the metal) B1
 $\frac{1}{2} m v_{\max}^2$ Maximum K.E / E_k of electron B1
- (b)(i) $f = 3.0 \times 10^8 / 6.5 \times 10^{-7}$ C1
frequency = $4.6(2) \times 10^{14} \approx 4.6 \times 10^{14}$ A1
unit: hertz / Hz / s^{-1} B1
- (ii) $\phi = hf$ C1
 $\phi = 6.63 \times 10^{-34} \times 4.62 \times 10^{14} = 3.0(6) \times 10^{-19} \text{ (J)} \approx 3.1 \times 10^{-19} \text{ (J)}$
(Possible ECF) C1
 $\phi = 3.0(6) \times 10^{-19} / 1.6 \times 10^{-19}$ C1
work function energy = 1.9(1)(eV) A0
(Answer of 1.91(eV) without supporting calculations scores 2/3)
- (c) (Rate / number of) electrons / photons increases C1
(Rate of / number of) photons double, \therefore (Rate of / number of) electrons double A1

[Total: 11]

8. Electrons behave like a wave C1
Moving / travelling electrons behave like a wave A1
Interference / diffraction effects are associated with 'waves' B1
Wavelength of electron is 'comparable to' / same as / atomic size / separation B1
Sensible experimental detail, e.g.: 'Diffraction rings' or 'Diffracted by carbon' B1
- $\lambda = h/p$ / $\lambda = h/mv$ B1
 λ for the person calculated, $\lambda \sim 10^{-36} \text{ m}$ B1
 λ of person (very) small (compared with gap to show diffraction) B1

[Total: 8]

9. Any one from: B1x1
- Travel at the speed of light / $3 \times 10^8 \text{ ms}^{-1}$ (in vacuum)
 - Travel in vacuum
 - Transverse waves
 - Consists of oscillating electric and magnetic fields
 - Can be reflected / diffracted / refracted / polarised etc.

Principal radiation named M1x3
 One sensible application for each (See guide below) A1x3

Guide:

<ul style="list-style-type: none"> γ-rays X-rays u.v. visible i.r. microwaves radio (waves) 	<ul style="list-style-type: none"> Sterilization (of food) / radiotherapy / treatment of cancer (X-ray) pictures of bones / flaws in pipes Sterilization (equipment) / fluoresce (powders/paint) / suntan beds Photography / seeing things with eye Security / i.r. camera / (TV) remote control microwave oven for cooking / communication / mobile phones Communication / commercial broadcast (not just 'radio') / T.V
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[Total: 7]

QWC applied to Q8 and Q9
 (See marking criteria) [4]