ELECTRONS + PHOTONS

1. (a)(i)	Coulomb / C	(Allow Ampere second / As)	B1
(i)	Voltmeter		B1
(c)(i)	P = VI	(Allow other variant)	C1
	V = 36 / 3.0		C1
	p.d. = 12 (V)		A1
(ii)	E = 36 x 600		C1
	energy = 2.1(6) x 10^4 (J) = 2.2 x 10^4 (J)		A1
(i)	ΔQ = IΔt / Q = It	(Allow other variant)	C1
	ΔQ = 3.0 x 600		C1
	charge = 1.8 x 10^3 (C)		A1
(v)	N = 1.8 x 10^3 / 1.6 x 10^{-19} (Possible ECF)		C1
	number = 1.1(3) x 10^{22} ≈ 1.1 x 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)	∝ V / I ÷ V = constant		C1
	Current ∝ p.d. / p.d. ÷ current = constant and (metallic conductor at) constant temperature		A1
	(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 coil 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)	$P = V^2 / V^2 / R / I^2 R$		C1
	power = 3.0 x 0.06		
	power = 0.18 (W) (Possible ECF)		A1
(b)(i)	'Constant temperature implies (wire)		B1
	(Do not allow reference to Ohm's law or to 'heating')		
(ii)	1. 40 (Ω)		B1
	2. $A = \pi \times (1.0 \times 10^{-3})^2 = 3.1(4) \times 10^{-6}$ (m^2)		B1
	$R = \rho L/A$	(Allow other variant)	C1
	$40 = 5.4 \times 10^{-5} \times L / 3.1\ (4) \times 10^{-6}$	(Possible ECF)	C1
	$L = 3.23(3)$ (m) ≈ 0.25 (m)		A1
	Length is 8cm) long, therefore must be coiled (wire)		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 3 C		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)	$R = R_1 + R_2 / 1.60 = r + 1.10 / r = (1.28 - 0.5 \times 1.1) / 0.8$		C1
	$r = 0.5(0)$ (Ω) = 0.5 (Ω)	(Possible ECF)	A1
(iii)	p.d. = 1.10 x 0.80 = 0.88 (V)	(Possible ECF)	B1
			(Total: 10)

5. (a)(i)	Decreases		B1
(i)	Decreases		B1
(ii)	$V = V_S \times R_2 / R_1 + R_2$ $V = 5.0 \times 420 / (1000 + 420)$ p.d. = 1.4(1) (V) = 1.5 (V) (Answer of 3.5(2) (V) scores 2/3)	$V = IR$ and $R = R_1 + R_2$ $I = 5.0 / 1420 = 3.52 \times 10^{-3}$ (A) p.d. = $3.52 \times 10^{-3} \times 420 = 1.5$ (V)	C1 C1 A1
(i)	1. $R = R_1R_2 / R_1 + R_2 = 420 \times 50 / 420 + 50$ (=44.7 (Ω))		B1
	2. $V = 5.0 \times 45 / (1000 + 45)$ p.d. = 0.21(5) (V) = 0.22 (V) (Allow V = 0.2 (V) as long as working is shown)	$I = 5.0 / 1045 = 4.78(5) \times 10^{-3}$ (A) p.d. = $4.78 \times 10^{-3} \times 420 = 0.22$ (V)	C1 A1
			[Total: 5]
6. (a)(i)	Correct direction of field (clockwise) Concentric circles round wire (Judge by eye) Increasing separation between successive circles (> three lines)		B1 M1 A1
(i)	1. (Fleming's) Left hand rule B1		
	2. To the left / Towards the other wire (No ECF from (a)(i)) Can score on Fig.6.1		B1
(b)(i)	$B = F / IL$ F = force, I = current and L = length of conductor / wire (in the field) (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 2/2)		M1 A1
	The conductor / wire normal to field		A1
(ii)	$F = 2.5 \times 10^{-2} \times 3.0 \times 2.0$ force = 1.5×10^{-1} (N)		C1 A1
			[Total: 10]

7. (a) hf: Photon energy / quantum of energy B1
ϕ Work function (energy for the metal) B1
$\frac{1}{2}mv_{max}^2$ Maximum K.E. / E_k of electron B1

(b)(i) $f = 3.0 \times 10^8 / 6.5 \times 10^{-7}$ C1
Frequency = $4.6(2) \times 10^{14} = 4.6 \times 10^{14}$ A1
unit: Hertz / Hz / s^{-1} B1

(ii) $\phi = hf$ C1
$\phi = 6.63 \times 10^{-34} \times 4.62 \times 10^{14} = 3.0(6) \times 10^{-19}$ (J) = 3.1×10^{-19} (J)
(Possible ECF) C1
$\phi = 3.0(6) \times 10^{-19} / 1.6 \times 10^{-19}$ C1
work function energy = 1.91(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, ∴ (Rate of / number of) electrons double A1

[Total: 11]

8 Electrons behave like a wave C1
Moving / travelling electrons behave like a whole 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, $\lambda = 10^{-36}$ m B1
λ of person (very) small (compared with gap to show diffraction) B1

[Total: 8]

8. Any one from: B1x1
Travel at the speed of light / 3×10^8 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:

γ-rays	Sterilization (of food) / radiotherapy / treatment of cancer
X rays	(X-ray) pictures of bones / flaws in pipes
u.v.	Sterilization (equipment) / fluoresce (powders/paint) / sunbeds
visible	Photography / seeing things with eye
i.r.	Security / i.r. camera / (TV) remote control
microwaves	microwave oven for cooking / communication / mobile phones
radio (waves)	Communication / commercial broadcast (not just radio) / TV

(Total: 7)

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