1. (a) A: gamma \ γ (ray \ radiation \ wave) $\lambda \rightarrow 10^{-16}$ to $10^{-10}$ (m) B1, B1
B: infrared \ IR \ i r $\lambda \rightarrow 7 \times 10^{-7}$ to $10^{-4}$ (m) B1 B1

(b) Any two from: B1 × 2
Travel at the speed of light \ $3 \times 10^8$ ($ms^{-1}$) (in vacuum)
Can travel in a vacuum (do not allow 'space')
Consists of oscillating electric and magnetic fields
Transverse waves \ can be polarised
Can be diffracted \ reflected \ refracted

[Total: 6]

2. (a)(i) Movement \ flow of charge(d) (particles) B1

(ii) $\Delta Q = I \Delta t$ \ $Q = It$ (Allow other correct subject) C1
charge = $0.350 \times 600$ (-1 for $10^x$ error) C1
charge = 210 (C) A1

(b) Correct direction for electron flow shown on Fig.2.1 B1

[Total: 5]

3 (a) length B1
cross-sectional area B1
material \ metal \ substance B1
temperature \ resistivity (Do not allow 'heat' for 'temperature') B1
(Allow 'conductivity', if used in the right context)

(b)(i) $R = \rho L/A$ (Allow other correct subject) C1
$A = \pi (6.0 \times 10^{-4})^2$ ($= 1.13 \times 10^{-6}$) ($m^2$) C1
$R = 8.0 \times 10^{-5} \times 10 \times 10^{-2} / 1.13 \times 10^{-6}$ (-1 for $10^x$ error) C1
$R = 0.707 \approx 0.71$ ($\Omega$) A1

(ii) $I = V / R$ (Allow other correct subject) C1
$I = 12 / 0.707 = 17$ (A) (Possible ECF) A1

[Total: 10]

4 (a) $R = R_1R_2 / R_1 + R_2$ \ $1/R = 1/R_1 + 1/R_2$ C1
$R = 6.0 \times 2.0 / (6.0 + 2.0)$ \ $1/R = 1/2.0 + 1/6.0$ C1
$R = 1.5$ ($\Omega$) A1

(b) $P = VI$ \ $I^2R$ \ $V^2/R$ C1
$P = 12^2 / 2.0$ C1
$P = 72$ (-1 if P = 24 (W) for coil Y) A1
unit: W \ $Js^{-1}$ B1

[Total: 7]

5 (a)(i) One tick only for JC' B1

(ii) N e m f = 4 5 – 1 5 (= 3.0) C1
V = 3 0 - 0 2 = 2.8 (V) (Ignore s gn) A1

(b)(i) $V = V_0 \times R_2 / R_1 + R_2$ | $R = V / I$ and $R = R_1 + R_2$ C1
$V = 5.0 \times 4.7 / (2.4 + 4.7)$ | $I = 5.0 / 7100 = 7.04 \times 10^{-4}$ (A) C1
| $V = 7.04 \times 10^{-4} \times 4700$
$V = 3.31 \approx 3.3$ (V) | $V = 3.31 = 3.3$ (V) A1
(Answer of 1 69 ≈ 1 7 (V) scores 2/3)

(ii) Decreases (Do not allow the mark if there is a contradiction) B1

[Total 7]

6 (a) (flat circular) coil \ solenoid B1

(b) $F = BIL$ (Allow other correct subject) C1
$I = 6.0 \times 10^{-4} / (0.36 \times 4.5 \times 10^{-2})$ (-1 for $10^n$ error) C1
$I = 3.70 = 3.7$ (A) A1

(c) Any two from
Earth's (magnetic) field is (very) weak B1 × 2
Cables have large weight \ mass
The current is alternating (therefore average force = 0)
The field may be at an angle to the cable (other than 90°)
Force due to magnetic field is small
The current (in the cable) is small

[Total: 6]

7 (a) $\lambda = h / p$ | $\lambda = h / mv$ M1
All symbols defined | A1
($\lambda$ = wavelength, p = momentum & h = Planck constant) | ($\lambda$ = wavelength, m = mass, v = velocity \ speed & h = Planck constant)

(b) (Moving electrons) show diffraction \ interference effects M1
'Target' identified (e.g., matter \ atoms \ nuclei \ slit(s) – if qualified ) A1

(c)(i) $\lambda = 6.63 \times 10^{-34} / 2.3 \times 10^{-19}$ (Possible back credit for (a)) C1
$\lambda = 2.88 \times 10^{-15} \approx 2.9 \times 10^{-15}$ (m) A1

(ii) 1. Same B1

2. Increases by a factor of two B2
(Increases scores 1 mark)

[Total: 9]

8. Total for question: 8 marks (maximum of 6 marks for either behaviour)

*QWC applies to this question – (1 mark for spelling, punctuation and grammar and 1 mark for technical language/organisation.)*

**Wave behaviour.....**

| | |
|---|---|
| Shows diffraction (Can score for a good diagram) | B1 |
| Diffracted by 'holes' \ slits \ grating | B1 |
| (Diffraction noticeable) when size of 'gap' is comparable to $\lambda$ | B1 |
| Experimental evidence: fringes \ rings | B1 |
| Reference to $v = f\lambda$ | B1 |
| Shows interference | B1 |
| Shows polarisation | B1 |

(-1 if electromagnetic wave is confused with 'electron as a wave', e.g.: "*electromagnetic waves obey the de Broglie equation*")

**Particle-like behaviour.....**

| | |
|---|---|
| This behaviour explains 'interaction' (of EM waves with matter) | B1 |
| (Energy of photon given by) $E = hf$ \ $E = hc/\lambda$ | M1 |
| Symbols defined: E = energy of photon, c = speed of light (in vacuum), f = frequency & $\lambda$ = wavelength | A1 |
| Evidence provided by photoelectric (effect) | B1 |
| • One-to-one interaction between photon and electron | B1 |
| • Energy is conserved \ $hf = \phi + \frac{1}{2} m v^2$ \ $hf = \phi + KE$ \ $hf \geq \phi$ for emission | B1 |
| • Effect of frequency<br>E.g.: emission of electrons for u.v. (but not visible light for zinc)<br>Or correct reference to threshold frequency | B1 |
| • Surface electrons are involved | B1 |
| Other evidence for this behaviour<br>(GM tube and detection of $\gamma$ 'particles', radiation pressure, etc) | B1 |

(-1 if photons are confused with particle-like properties of electrons, e.g. "*photons have charge*")

[Total: 8]