OCR
RECOGNISING ACHIEVEMENT

**OXFORD CAMBRIDGE AND RSA EXAMINATIONS**

**Advanced Subsidiary GCE**

# PHYSICS A — 2822

Electrons and Photons

Tuesday **23 JANUARY 2001** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

| Candidate Name | Centre Number | Candidate Number |
|---|---|---|
| | | |

**TIME** 1 hour 30 minutes

## INSTRUCTIONS TO CANDIDATES

- Write your name in the spaces above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

## INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

| FOR EXAMINER'S USE | | |
|---|---|---|
| **Qu.** | **Max.** | **Mark** |
| **1** | **13** | |
| **2** | **13** | |
| **3** | **6** | |
| **4** | **10** | |
| **5** | **8** | |
| **6** | **12** | |
| **7** | **16** | |
| **8** | **8** | |
| **QWC** | **4** | |
| **TOTAL** | **90** | |

**This question paper consists of 17 printed pages and 3 blank pages.**

SB (SJF1602/PW) QA15531/5

**Data**

| | |
|---|---|
| speed of light in free space, | $c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$ |
| permeability of free space, | $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$ |
| permittivity of free space, | $\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ |
| elementary charge, | $e = 1.60 \times 10^{-19}\ \mathrm{C}$ |
| the Planck constant, | $h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$ |
| unified atomic mass constant, | $u = 1.66 \times 10^{-27}\ \mathrm{kg}$ |
| rest mass of electron, | $m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$ |
| rest mass of proton, | $m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$ |
| molar gas constant, | $R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$ |
| the Avogadro constant, | $N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$ |
| gravitational constant, | $G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$ |
| acceleration of free fall, | $g = 9.81\ \mathrm{m\,s^{-2}}$ |

**Formulae**

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \dfrac{1}{\sin C}$

capacitors in series, $1/C = 1/C_1 + 1/C_2 + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0\, e^{-\lambda t}$

$\lambda t_{\frac{1}{2}} = 0.693$

critical density of matter in the Universe, $\rho_0 = \dfrac{3H_0^2}{8\pi G}$

relativity factor, $\gamma = \sqrt{\{1 - \dfrac{v^2}{c^2}\}}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $IL = 10 \lg \left(\dfrac{I}{I_0}\right)$



[Turn over

For Examiner's Use

Answer **all** questions.

1 **(a)** Name an instrument used to measure

**(i)** electric current,

........................................................................................................................ [1]

**(ii)** potential difference.

........................................................................................................................ [1]

**(b)** The electric charge $\Delta Q$ passing a point in a circuit is given by the equation

$$\Delta Q = I\Delta t.$$

State what is represented by the other symbols $I$ and $\Delta t$.

$I$: ........................................................................................................................

$\Delta t$: ........................................................................................................................ [2]

**(c)** A 1.2 kW water heater is switched on for 1500 s. During this time, a charge of $7.5 \times 10^3$ C passes. Calculate

**(i)** the electric current,

current = .............................. A [2]

**(ii)** the p.d. across the heater,

p.d. = .............................. V [3]

For Examiner's Use

(iii) the electrical energy transformed by the heater,

energy = ............................... J [2]

(iv) the cost of using the heater given that the cost of 1 kW h is 6.4 p.

cost = ............................... p [2]

2 **(a)** Define electrical resistance.

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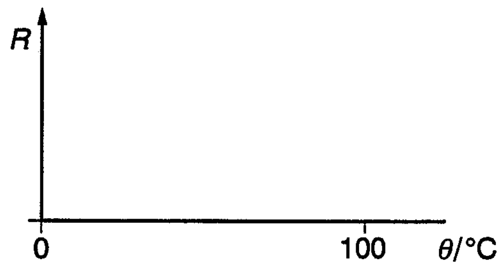
.......................................................................................................................... [2]

**(b)** With the aid of a sketch graph, describe how the resistance $R$ of a negative temperature coefficient (NTC) thermistor changes with temperature $\theta$.

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**(c)** Fig. 2.1 shows the $I/V$ characteristic of a tungsten filament lamp.

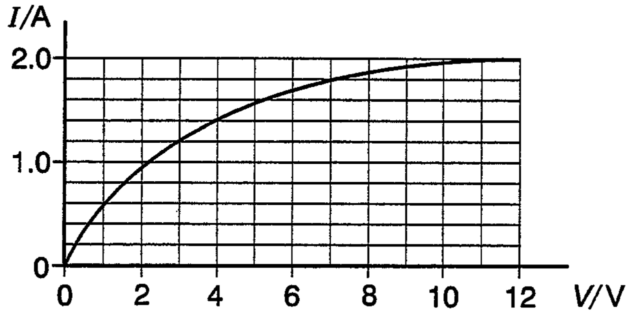


**Fig. 2.1**

**(i)** State how, and explain why, the resistance of the filament lamp changes as the potential difference $V$ across it increases.

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.......................................................................................................................... [2]

For Examiner's Use

**(ii)** A 5.0 Ω resistor and the tungsten filament lamp are connected in series to a d.c. power supply of e.m.f. 24 V. The current drawn from the power supply is 2.0 A.

**1.** Calculate the total power delivered by the supply.

power ............................ W [2]

**2.** Use **Fig. 2.1** to determine the resistance of the filament lamp when the current in it is 2.0 A.

resistance = ............................ Ω [2]

**3.** Calculate the total resistance of the series combination of the filament lamp and the resistor.

resistance = ............................ Ω [1]

**4.** Calculate the internal resistance of the supply.

internal resistance = ............................ Ω [2]

For Examiner's Use

3 **(a)** Define electrical resistivity.

..............................................................................................................

.............................................................................................................. [2]

**(b)** Fig. 3.1 illustrates a metallic resistor constructed by depositing a thin layer of metal on a plastic strip. This particular resistor has resistance 5.0 Ω, length $1.2 \times 10^{-2}$ m and width $2.0 \times 10^{-3}$ m.

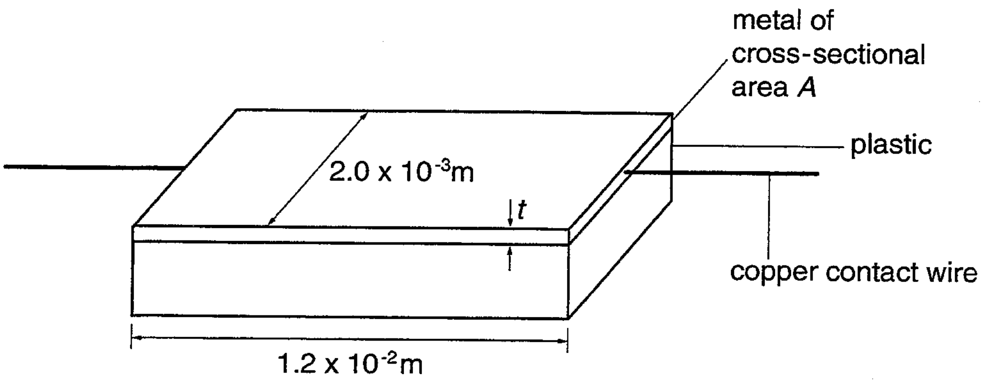


**Fig. 3.1**

**(i)** The resistivity of the metal is $4.3 \times 10^{-6}$ Ω m. Calculate the cross-sectional area *A* of the resistor.

*A* = .............................. $m^2$ [3]

**(ii)** What is the thickness *t* of the resistor?

*t* = .............................. m [1]

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For Examiner's Use

4 **(a)** Kirchhoff's first law is based on the conservation of an electrical quantity. State the law and the quantity conserved.

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**(b)** Fig. 4.1 shows a potential divider circuit. The battery has negligible internal resistance and the voltmeter has very high resistance.

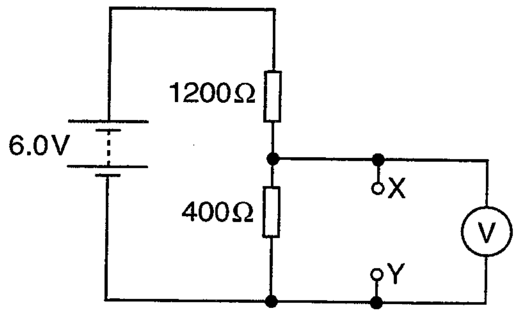


**Fig. 4.1**

**(i)** Show that the voltmeter reading is 1.5 V.

[2]

**(ii)** An electric device rated at 1.5 V, 0.1 A is connected between the terminals X and Y. The device has constant resistance. The voltmeter reading drops to a very low value and the device fails to operate, even though the device itself is not faulty.

**1.** Calculate the total resistance of the device and the 400 Ω resistor in parallel.

resistance = .............................. Ω [3]

**2.** Calculate the p.d across the device when it is connected between X and Y.

p.d. = .............................. V [2]

**3.** Why does the device fail to operate?

.................................................................................................................. [1]

For Examiner's Use

5 **(a)** Figs. 5.1 and 5.2 illustrates the magnetic field patterns caused by current-carrying conductors in a plane at right angles to the conductors.

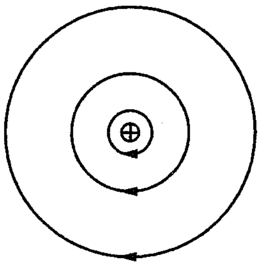

**Fig. 5.1**

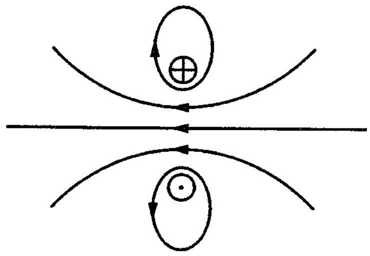

**Fig. 5.2**

What **shapes** of conductor would produce these field patterns above?

Fig. 5.1 ..........................................................................................................

Fig. 5.2 .......................................................................................................... [2]

For Examiner's Use

**(b)** Fig. 5.3 illustrates a part of a simple electric motor. A square loop of wire ABCD is placed in the uniform magnetic field of a permanent magnet.

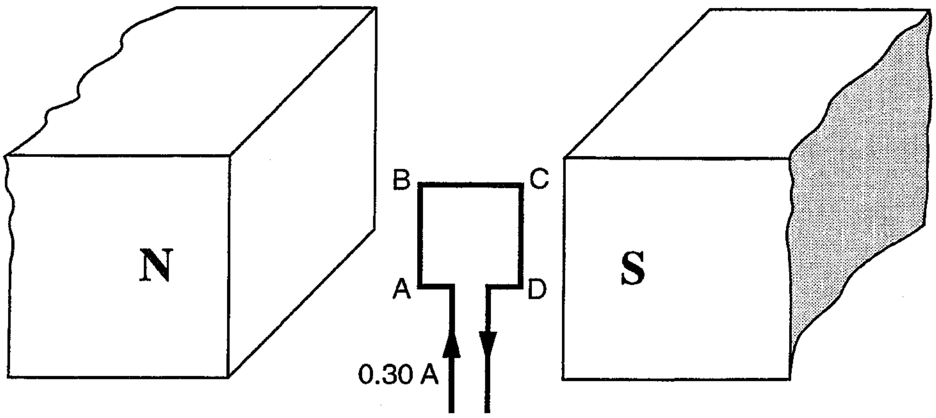


**Fig. 5.3**

AB is perpendicular to the magnetic field lines and BC is parallel to them. The current in the loop is 0.30 A and the magnetic flux density is $1.2 \times 10^{-2}$ T.

**(i)** State the magnitude of the force, if any, experienced by the side BC.

........................................................................................................................ [1]

**(ii) 1.** The length of the side AB is 1.5 cm. Calculate the magnitude of the force experienced by AB.

force = ............................ unit ............................ [4]

**2.** Name the rule that may be used to find the direction of the force experienced by AB.

........................................................................................................................ [1]

6 In 1927, the American physicist Clinton Davisson showed that electrons were diffracted by solid materials.

(a) State what may be interpreted about the nature of electrons from such an experiment.

........................................................................................................................ [1]

(b) (i) State the de Broglie equation, giving the meanings of the symbols used.

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(ii) Electrons in outer space can travel at very high speeds. One particular electron has kinetic energy 0.01 MeV.

1. Show that the kinetic energy of the electron is $1.6 \times 10^{-15}$ J.

[2]

2. Calculate the speed of this 0.01 MeV electron.

speed = .............................. $m\,s^{-1}$ [3]

For Examiner's Use

3. Hence determine the de Broglie wavelength $\lambda$ of this electron.

$\lambda$ = .............................. m [2]

**(c)** State and explain whether a 0.01 MeV proton would have a shorter, equal or a longer wavelength than that calculated in **(b)(ii)3**.

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For Examiner's Use

7 **(a)** In an experiment, an electrically insulated zinc plate is negatively charged. When exposed to a weak ultra-violet source, the plate starts to lose its negative charge.

Explain this phenomenon in terms of the photoelectric effect. Suggest how increasing the intensity of the ultra-violet source would affect the experiment.

(You will be awarded marks for the quality of written communication in your answer to this question.)

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**(b)** A 1.0 mW laser produces red light of wavelength $6.3 \times 10^{-7}$ m.

**(i)** Calculate

**1.** the frequency of the radiation,

frequency = .............................. unit ............ [3]

**2.** the energy of a photon of red light.

energy = .............................. J [2]

**(ii)** Calculate the number of photons emitted per second by the laser.

number = .............................. $s^{-1}$ [2]

**(iii)** State how, and explain why, the number of photons emitted per second would change if the 1.0 mW laser produced blue light.

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For Examiner's Use

8 Describe the main features of electromagnetic waves. Name three principal radiations and give their approximate wavelengths.

(You will be awarded marks for quality of written communication in your answer to this question.)

..................................................................................................................................... [8]

Quality of written communication [4]

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| | | | |
|---|---|---|---|
| 1(a)(i) | Ammeter | | B1 |
| (ii) | Voltmeter | | B1 |
| (b) | $I$: current | | B1 |
| | $\Delta t$: time (interval / duration) | | B1 |
| (c)(i) | $I = 7.5 \times 10^3 / 1500$ | | C1 |
| | $I = 5.0$ (A) | | A1 |
| (ii) | $V = P / I$ | (allow other variants) | C1 |
| | $V = 1.2 \times 10^3 / 5.0$ | (possible e.c.f) | C1 |
| | $V = 240$ (V) | (-1 for missing k or $10^3$ factor) | A1 |
| (iii) | $E = 1.2 \times 10^3 \times 1500$ | | C1 |
| | $E = 1.80 \times 10^6$ (J) | (-1 for missing k or $10^3$ factor) penalise once only in (ii) & (iii) | A1 |
| (iv) | units = 1500/3600 x 1.2 = 0.5 | units = $1.8 \times 10^6 / 3.6 \times 10^6 = 0.5$ | C1 |
| | cost = 0.5 x 6.4 = 3.2 (p) | (possible (e.c.f if (iii) used) | A1 |
| 2(a) | $R = V / I$ | | C1 |
| | symbols defined: $R$ = resistance, V = p.d. / voltage and $I$ = current | | A1 |
| | ( $V = IR$ with all symbols defined scores 1/ 2) | | |
| | ( $R$ = p.d. / voltage per unit current scores 2/2) | | |
| | ( $R$ = p.d. / voltage per unit amp / A scores 1/ 2) | | |
| (b) | Resistance decreases as temperature increases. | | B1 |
| | Correct <u>curve</u> with $R$ decreasing as temperature increases. | | B1 |
| (c)(i) | Resistance increases (as $V$ increases) | | B1 |
| | Temperature increases / atoms vibrate more / more electron collisions (with atoms) | | B1 |
| (ii) | **1.** $P = 24 \times 2$ | | C1 |
| | $P = 48$ (W) | | A1 |
| | **2.** $V = 12$ (V) when current is 2.0 (A) | (Allow $V = 11.0$ V from graph) | C1 |
| | $R = 12 / 2.0 = 6.0$ (Ω) | | A1 |
| | **3.** $R_T = 6.0 + 5.0 = 11.0$ (Ω) | (possible e.c.f) | B1 |
| | **4.** $V_L = 11.0 \times 2.0 = 22$ (V) | $R_{circuit} = 48 / 2.0^2 = 12$ (Ω) | C1 |
| | $r = (24-22) / 2.0 = 1.0$ (Ω) | $r = 12.0 - 11.0 = 1.0$ (Ω) | A1 |
| 3(a) | $\rho = RA / L$ | | M1 |
| | Symbols defined: $\rho$ = resistivity, $A$ = <u>cross-sectional</u> area, R = resistance and $L$ = length | | A1 |
| | ( $R = \rho L/A$ with all symbols defined scores 1/ 2) | | |
| (b)(i) | $A = \rho L / R$ | | C1 |
| | $A = 4.3 \times 10-6 \times 1.2 \times 10^{-2} / 5.0$ | (-1 for using L as 2.0 mm) | C1 |
| | $A = 1.0(3) \times 10^{-8}$ ($m^2$) | | A1 |
| (ii) | $t = 1.0(3) \times 10^{-8} / 2.0 \times 10^{-3}$ | | |
| | $t = 5.1(6) \times 10^{-6}$ (m) | (possible e.c.f) | B1 |

| Question | Answer | Alternative / Notes | Mark |
|---|---|---|---|
| 4(a) | Sum of currents = zero (at junction) / | | |
| | sum of currents in = sum of currents out (at junction) | | B1 |
| | Charge is conserved. | | B1 |
| (b)(i) | $V = V_0 \times R_2 / (R_1 + R_2)$ | $R = V / I$ and $R = R_1 + R_2$ | C1 |
| | $V = 6.0 \times 400 / (1200 + 400)$ | $I = 6.0 / 1600 = 3.75 \times 10^{-3}$ (A) | |
| | | $V = 3.75 \times 10^{-3} \times 400$ | C1 |
| | $V = 1.5$(V) | $V = 1.5$(V) | A0 |
| | (Answer of 4.5 (V) scores 1/ 2) | | |
| (ii) | **1.** $R_D = 1.5 / 0.1 = 15$ ($\Omega$) | | C1 |
| | $R = R_1R_2 / (R_1 + R_2)$ / $1/R_T = \sum 1/R_1$ | | C1 |
| | $R = 400 \times 15 / (400 + 15) = 14.5 = 15$ ($\Omega$) (possible e.c.f) | | A1 |
| | **2.** $V \approx 6.0 \times 15 / (1200 + 15)$ | $I \approx 6.0 / 1200 + 15 \approx 4.98 \times 10^{-3}$ (A) | C1 |
| | $V \approx 0.07$ (V) | $V \approx 4.98 \times 10^{-3} \times 15 = 0.07$ (V) | A1 |
| | (Answer of 5.93 (V) scores 1/ 2) | | |
| | **3.** Resistance of device is small(er) / current in device is small(er) / p.d. across device is small(er) | | B1 |
| 5(a) | Fig. 5.1: (long straight) wire / conductor | | B1 |
| | Fig. 5.2: (single) coil / two (parallel) wires | | B1 |
| (b)(i) | Zero | | B1 |
| (ii) | **1.** $F = BIL$ | | C1 |
| | $F = 1.2 \times 10^{-2} \times 0.30 \times 1.5 \times 10^{-2}$ | | C1 |
| | $F = 5.4 \times 10^{-5}$ | (-1 for L = '1.5') | A1 |
| | Unit: newton / N | (do not allow **n**) | B1 |
| | **2.**(Fleming's) L.H.R | | B1 |
| 6(a) | (Moving) electrons behave like a wave | | B1 |
| (b)(i) | $\lambda = h / p$ | $\lambda = h / mv$ | M1 |
| | $\lambda$ = wavelength, $p$ = momentum | $\lambda$ = wavelength, $m$ = mass and $v$ = velocity / speed | A1 |
| (ii) | **1.** $E = 0.01 \times 10^6 \times 1.6 \times 10^{-19}$ | | |
| | **$10^6$** factor in answer | | M1 |
| | use of **$1eV = 1.6 \times 10^{-19}$** (J) in answer | | M1 |
| | $E = 1.6 \times 10^{-15}$ (J) | | A0 |
| | **2.** $E_k = ½ m v^2$ | | C1 |
| | $1.6 \times 10^{-15} = 0.5 \times 9.1 \times 10^{-31} \times v^2$ | | C1 |
| | $v = 5.9(3) \times 10^7$ ($ms^{-1}$) | | A1 |
| | **3.** $\lambda = 6.63 \times 10^{-34} / 9.1 \times 10^{-31} \times 5.9(3) \times 10^7$ | | C1 |
| | $\lambda = 1.2(3) \times 10^{-11}$ (m) | (possible e.c.f) | A1 |
| (c) | Shorter wavelength | | B1 |
| | Mass of proton is larger (than an electron's). | | B1 |

| | | |
|---|---|---|
| 7(a) | Any five from: | B1 x 5 |

- Photons are involved / $E = hf$
- Surface electrons are involved.
- One-to-one exchange of energy between photon and electron
- Electrons carry negative charge, therefore removal means reduction in (negative) charge (of plate).
- Electron released when photon energy > workfunction (energy).
- Electron emission related to threshold frequency.
- Energy conserved in the interaction (between photon and electron).
- Einstein's equation mentioned ( $hf = \frac{1}{2} mv^2 + \phi$ ).

Any two from:
More photons (in a given time).
More electrons are removed (in a given time)
The plate loses charge quicker. B1 x 2

| | | |
|---|---|---|
| (b)(i) | **1.** $f = 3.0 \times 10^8 / 6.3 \times 10^{-7}$ | C1 |
| | $f = 4.7(6) \times 10^{14}$ | A1 |
| | unit: hertz / Hz | B1 |
| | **2.** $E = h f$ | C1 |
| | $E = 6.63 \times 10^{-34} \times 4.76 \times 10^{14} = 3.1(6) \times 10^{-19}$ (J) (possible e.c.f) | A1 |
| (ii) | $N = 1 \times 10^{-3} / 3.16 \times 10^{-19}$ (possible e.c.f) | C1 |
| | $N = 3.1(7) \times 10^{15}$ ($s^{-1}$) | A1 |
| (iii) | Energy of photon is greater/ blue light has shorter wavelength. | B1 |
| | Reduced (rate) of photons / fewer photons (in a given time) | B1 |

| | | |
|---|---|---|
| 8 | Any two from: | B1 x 2 |

- Travel at the speed of light / $3 \times 10^8$ ($ms^{-1}$)(in vacuum).
- Travel in vacuum / space.
- Transverse waves.
- Oscillating electric and magnetic fields.
- Can be reflected / diffracted / refracted / polarized etc.

Principal radiation named. B1 x 3
Correct wavelength. (see guide below) B1 x 3

| Guide: | | |
|---|---|---|
| | $\gamma$-rays | $10^{-16} - 10^{-12}$ m |
| | X-rays | $10^{-11} - 10^{-9}$ m |
| | u.v | ~ $10^{-8}$ m |
| | visible | ~ $10^{-7}$ m |
| | i.r | ~ $10^{-6}$ m |
| | microwaves | $10^{-4} - 10^{-2}$ m |
| | radio waves | > $10^{-1}$ m |

(If unit for wavelength not given, then penalty of –1)

QWC applied to Q7 & Q8 Maximum of 4 marks