



2.

Instructions to Candidates

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over the flap and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiner may require you to write in legible script or have it typed and the expense of typing will be charged to the candidate.
4. Write your answers in ink.
5. Begin each answer on a fresh page. Do all rough work in the answer book and cross it through.
6. No part of this book is to be torn out; it must be handed in complete.
7. If more books than one are used, fasten them together using the tags available from the invigilator(s).
8. **Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.**

1	Student Number	2111739
2	Title of Examination Paper	~~ACDC5009~~ Electromagnetic Radiation
3	Module Code	ACDC5009
4	Date and Time of Examination	3/05/23 09:00
5	Examination Venue	UWTS D 1G Building, Swansea
6	Seat Number	006
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	12 ✓
2	10 ✓
3	6 ✓
4	8 ✓
5	8 ✓
Total	e.g. f r s

44
100
PLP

(Gweler yr ochr arall am y fersiwn Cymraeg)

44/150

1 a An electromagnetic wave is a transverse wave which is comprised of ~~an~~ electric and magnetic waves that oscillate in phase, perpendicular to the direction of travel.

1 b Properties of Electromagnetic Waves:

- Transverse
- Electric & Magnetic fields oscillate ~~perpendicular~~ perpendicular to the direction of travel.
- Can be polarised.
- Do not require a medium to travel through.
- Electric and Magnetic fields are at 90° to each other.

1 c An electromagnetic wave propagates ~~by~~ through alternating oscillating Electric and Magnetic fields. The Electric field induces a Magnetic field and vice versa.

1 d An electromagnetic Spectrum is the range of frequencies ~~considered to~~ EM waves oscillate at.

Applications of radio waves:

- Tracking objects
- Measuring distance
- Measuring speed
- Satellite Communication
- Radio handset communication

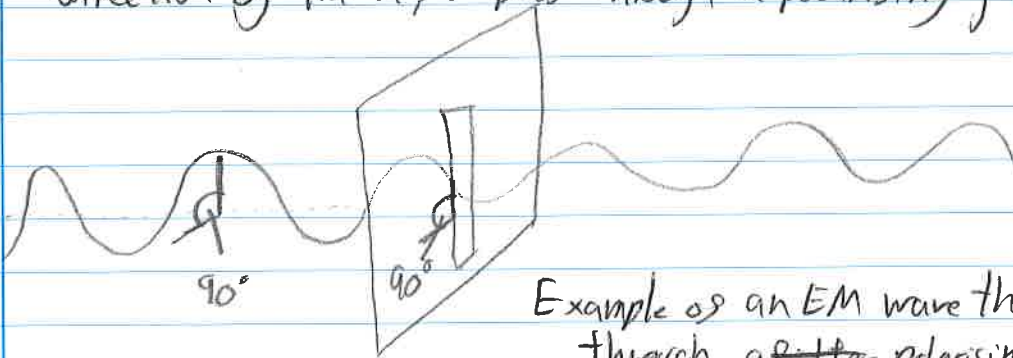
9

$$2 + 5 + 2 + 3 = 12$$

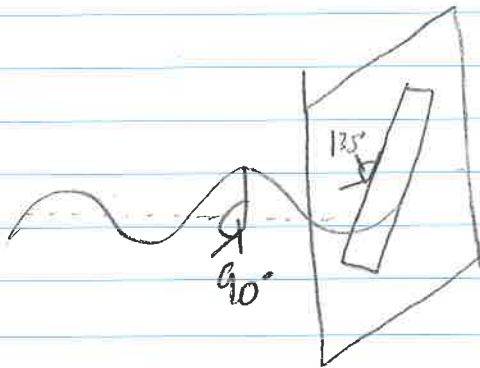
12

2 a

Polarisation is the process of only allowing EM waves oscillating in a particular direction, perpendicular to their direction of travel, to pass through a polarising filter.



Example of an EM wave that can pass through a polarising filter



Example of an EM wave that cannot pass through a polarising filter

2 b)

$$Q_1 = -20 \mu\text{C}$$

$$P(-6, 4, 6)$$

$$Q_2 = 50 \mu\text{C}$$

$$R(5, 8, -2)$$

Find the force exerted on Q_2 by Q_1 in free space

magnitude of force

$$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 d^2}$$

Distance :

$$\overline{PR} = P - R = (-6 - 5, 4 - 8, 6 - (-2))$$

$$= -11, -4, 8$$

$$|\overline{PR}| = \sqrt{(-11)^2 + (-4)^2 + (8)^2}$$

$$= \sqrt{201}$$

$$\approx 14.177 \text{ (3 d.p.)}$$

P.T.O. →

2b Distance = 14.177

$$\text{Force} = \frac{Q_1 Q_2}{4\pi\epsilon_0 d^2}$$

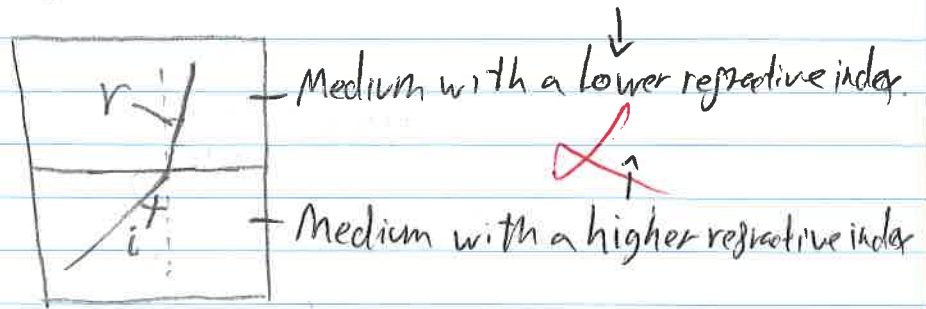
$$= \frac{-20\mu\text{C} \cdot +50\mu\text{C}}{4\pi\epsilon_0 \cdot 14.177^2}$$

$$= \underline{\underline{-0.0447 \text{ N}}}$$

Q2
1+3+2+2+2 = 10

3a i

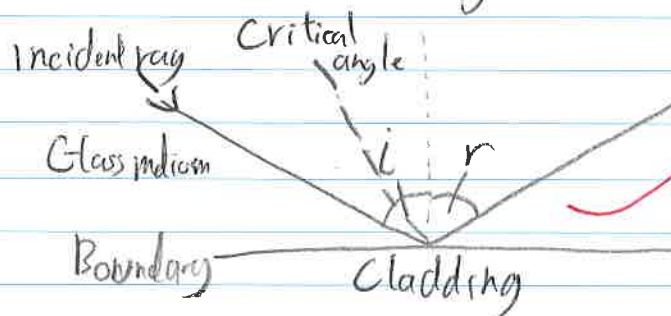
Diffraction is where an EM wave changes direction due to a change in medium.



3a ii

Total Internal Reflection

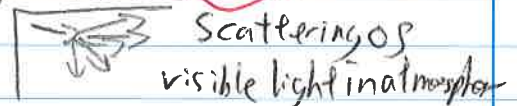
When an EM wave is incident to a boundary and the angle of incidence is ~~greater~~ ^{greater} ~~smaller~~ than the critical angle.



This is used in ~~optical~~ fibres to keep waves within

3a iii

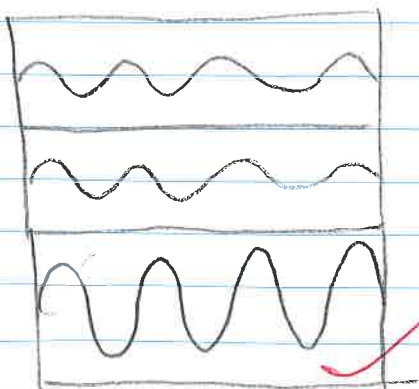
Scattering is where ~~light~~ EM waves come into contact with a medium and, due to the interaction of particles in that medium, they scatter in different directions.



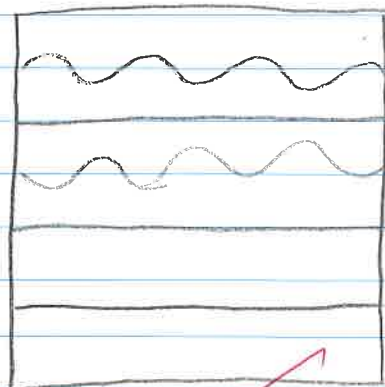
3a iv

Interference is the superposition of EM waves.

This is where the phase and amplitude of ~~a wave~~ more than one wave combine to form a resultant wave.



Constructive interference



Destructive Interference

3a v Reflection is where an incident EM wave is reflected by a boundary at an angle identical to the angle of incidence



Q3 = 2+2+2=6 ✓

4a

$$Q = \int_{\text{vol}} \rho_r dV$$

$$= \int_{\text{vol}} 10z^2 x \sin \pi y \quad -1 \leq x \leq 2, 0 \leq y \leq 1$$

$$3 \leq z \leq 3.6$$

$$= \int_{\text{vol}} 10z^2 x \sin \pi y \int_{\text{vol}} x \sin \pi y \int_{\text{vol}} x y \sin \pi y dy$$

$$= \left[10z^3 \right]_3^{3.6} \times \left[\frac{x^2}{2} \right]_{-1}^2 \times \left[-\pi \cos \pi y \right]_0^1$$

$$= \left(\left[10z^3 (3.6)^3 \right] - \left[10z^3 (3)^3 \right] \right) \times \left(\left[\frac{x^2}{2} \right] - \left[\frac{x^2}{2} \right] \right) \times \left(\left[-\pi \cos \pi y \right] - \left[-\pi \cos \pi y \right] \right)$$

$$= \left[\frac{1638}{25} \right] \times \left[-\frac{3}{2} \right] \times \left[-6.2784 \dots \right]$$

$$= 306.6 \text{ C/m}^3 \text{ (3.5.1)}$$

4b

Critical Angle $\phi_c = \sin^{-1} \frac{n_2}{n_1}$ $n_2 = 1.47$ $n_1 = 1.50$

$$\frac{1.47}{1.50} = 0.98$$

$$\phi_c = \sin^{-1} \frac{1.47}{1.5}$$

$$= 78.5^\circ$$

Acceptance angle $\phi_a = \sin^{-1} \frac{NA}{n_0}$

$$NA = \sqrt{n_2^2 - n_1^2}$$

$$NA = \sqrt{1.47^2 - 1.5^2}$$

$$= 0.2986$$

$$\phi_a = \sin^{-1} \left(\frac{0.298}{1.5} \right)$$

$$\phi_a = 0.0454$$

4c

laser:

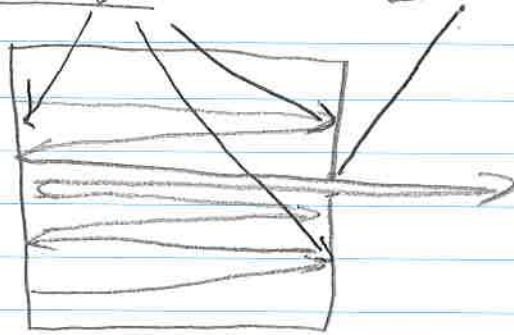
Photons collide with CO_2 molecules, which are excited and produce another photon Parallel.

Hydrogen restores the CO_2 molecules to a state where they can emit again.

Nitrogen takes the kinetic energy away from the Hydrogen Atom and is cooled.

0.050

There are reflective surfaces with a narrow slit allowing photons to escape.



$$P_4$$

$$2 + 2 + 2 + 1 + 1 = 8$$

5a Inductance per unit length co-axial cable
inner & outer radius of 1mm, 3mm
Relative permeability as unity

$$\frac{L}{d} = \frac{\mu}{2\pi} \ln(b/a) \text{ H/m}$$

$$= \frac{1}{2\pi} \ln\left(\frac{3 \times 10^{-3}}{1 \times 10^{-3}}\right) \quad \mu = 1$$

$$= \underline{0.17485 \text{ Hm}^{-1}}$$

5b Characteristic Impedance, Attenuation constant, Phase constant
 $Z_{oc} = 550 \angle -66^\circ \Omega$ $Z_{sc} = 500 \angle -14^\circ \Omega$

Assuming the second $Z_{oc} = Z_{sc}$ on the Question paper
and $Z_{oc} = 550 \angle -66^\circ \Omega$

Characteristic Impedance $Z_0 = \sqrt{Z_{oc} Z_{sc}}$

$$Z_0 = \sqrt{550 \angle -66^\circ \times 500 \angle -14^\circ}$$

$$Z_0 = \underline{524.4 \angle -37^\circ \Omega} \approx \underline{524 \angle -37^\circ \Omega} \text{ (3.5.3)}$$

Attenuation Constant $\gamma = \alpha + j\beta$

Polar to rectangular x (real) component = $r \cos \phi$

$$\gamma = 524.4 \cos(-14) + j\beta$$

$$= \underline{508.83} \text{ } 509 \text{ (3.5.3) Nepers/KM}$$

Phase Constant $\gamma = \alpha + j\beta$

Polar to rectangular y (imaginary) component = $r \sin \phi$

$$\gamma = \alpha + 524.4 \sin(-14) = \underline{426. -127 \text{ rad/KM}}$$

Question No.

Examiner Only