

ation of an
ires no
~~be used~~

12 Pages

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can read answers written in a legible script or have it typed and the expense of typing 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.**

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

46
100
PLA

1 a An electromagnetic wave is a combination of an electric ~~and~~ and ~~mag~~ magnetic wave. It requires no medium to propagate in and can be used to transmit data.

1 b Properties of electromagnetic waves:

- does not require a medium to propagate ✓
- travels at the speed of light in a vacuum ✓
- electric and magnetic wave at 90° to each other ✓
- typically 90° out of phase ✓

1 c An electromagnetic wave ^{self} propagates, by as the electric field increases in energy it induces an increase in the magnetic field which in turn induces a build in the electric field

1 d The Electromagnetic Spectrum is the range of Electromagnetic waves, sorted by frequency. Radio frequency waves, typically known as RF, is the region of the electromagnetic spectrum from 30 kHz to 300 GHz. RF is typically line of sight in its nature and, ~~consequently~~ easily absorbed by different mediums. RF waves are used extensively ~~in~~ in the modern world for communication systems, RADAR and imaging.

1 e TE mode, or Transverse Electric mode, is a phenomenon where by the electric field propagates at 90° to the magnetic field.

$$Q1 \\ 2+4+2+6+1=15$$

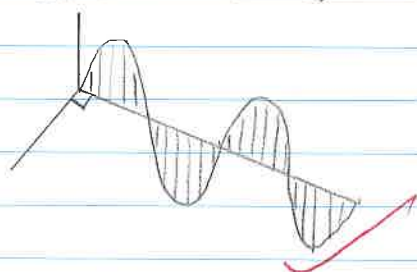
2 a

Polarisation is the phenomenon whereby the electromagnetic waves of a signal are all oscillating in the same direction.

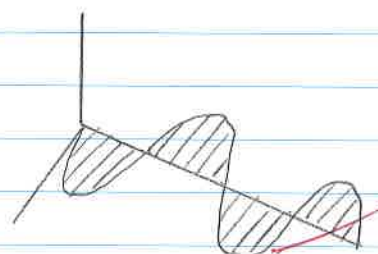
~~linear~~ ~~circular~~ ~~eclipse~~

Polarisation takes a few common forms:

Linear (vertical)

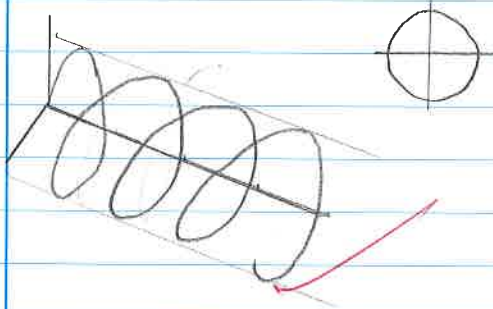


linear (horizontal)

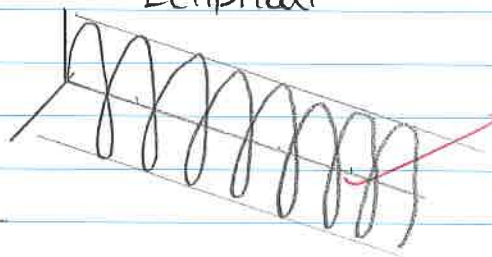


Linear ~~an~~ polarisation, in either the horizontal or vertical plane is very common in RF systems due to the orientation of an antenna when transmitting. ~~It can~~ It can also be found on electronic displays where polarising films can be added for privacy.

Circular



Elliptical



Circular and Elliptical polarisation are very similar in nature and often ~~are~~ used in communication systems ~~to~~ especially for satellites.

2b

charge Q_1 at $P(-6, 4, 6)$ $-20 \mu\text{C}$
 Q_2 at $R(5, 8, -2)$ $50 \mu\text{C}$
 distance in meters

find force on Q_2 by Q_1

$$\text{so } F_{Q_2 Q_1} = \frac{Q_2 Q_1}{4\pi \epsilon_0 d^2} \bar{a}_{Q_2}$$

$$F = k \frac{Q_1 Q_2}{d^2}$$

$$k = \frac{1}{4\pi \epsilon}$$

$$\begin{aligned} |\overline{PR}| &= \sqrt{(5 - (-6))^2 + (8 - 4)^2 + (-2 - 6)^2} \\ &= \sqrt{(11)^2 + (4)^2 + (-8)^2} \\ &= \sqrt{201} = 14.177 \text{ m} \end{aligned}$$

$$\epsilon = \epsilon_0 \epsilon_r$$

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

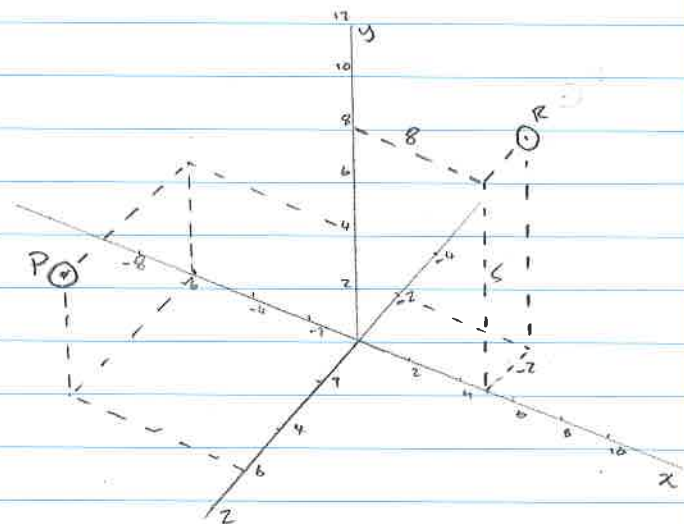
$$F = \frac{50 \times 10^{-6} \times -20 \times 10^{-6}}{4\pi \times 8.854 \times 10^{-12} \times \sqrt{201}^2}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$$

$$= -4.472 \text{ mN} \times 10^{-3}$$

$$= -44.72 \text{ nN}$$

$$\bar{a}_{Q_2} = \frac{\bar{r} - \bar{r}_2}{|\bar{r} - \bar{r}_2|}$$



PR

$$Q_2$$

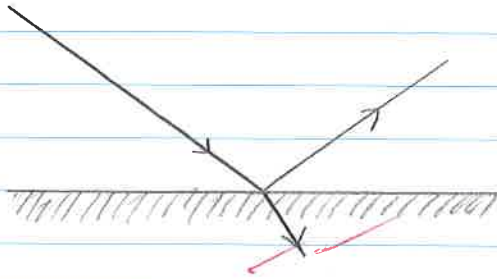
$$1+2+3+1+2+2+2+1=14$$

3a

Describe

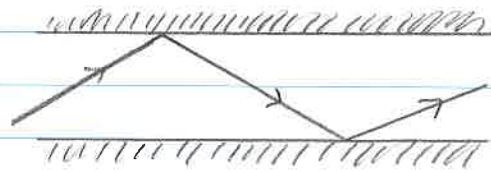
i Diffraction

Diffraction is the phenomenon whereby an electromagnetic wave enters a new medium and its angle of travel is altered.



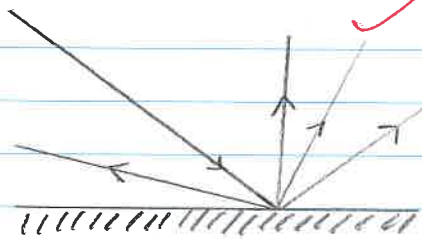
ii Total Internal Reflection

Total Internal Reflection is where an electromagnetic wave (typically light) is reflected within a medium with none diffracted externally.



iii Scattering

Scattering is where an electromagnetic wave is not uniformly reflected in any one direction.



iv Interference

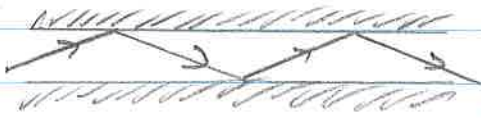
Interference

v Refraction

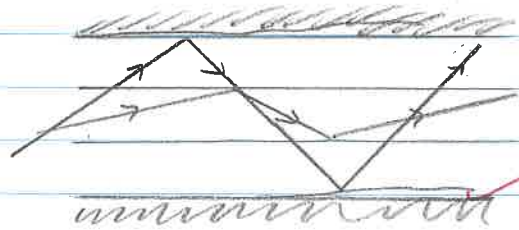
Refraction is the opposite to defraction and occurs when a wave exits a material of higher coefficient



3b a waveguide is a tool used to manipulate an electromagnetic wave into travelling along a desired path. Fiber optic cables are one form of waveguide of which the two most common are single mode and multi-mode.



Single mode fiber optic has a single core and allows the flow of a single signal.



multi-mode fiber optic as multiple cores within each other and allow multiple signals of different frequencies to travel.

Q3
 $2 + 2 + 2 + 3 + 2 + 2 = 13$

4a

$$\rho_v = 10^{-2} x \sin \pi y$$

$$\text{volume} = \begin{aligned} -1 \leq x \leq 2 \\ 0 \leq y \leq 1 \\ 3 \leq z \leq 3.6 \end{aligned}$$

$$\rho_v = \frac{\text{charge}}{\text{volume}}$$

$$\rho_v \times \text{volume} = \text{charge}$$

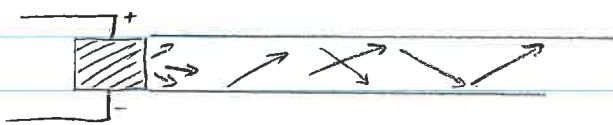
$$\rho_v \quad x \times z = 3 \times 0.6 = 1.8$$

$$\begin{aligned} x \times y \\ = 1.8 \times 1 = 1.8 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} 10^{-2} x \sin \pi y \times 1.8 &= \text{charge} \\ &= 25.569 \text{ C} \end{aligned}$$

4c

A laser works by energising a material to the point that it emits photons and directing the photons through a wave guide to provide a single directed stream of light.



4d

an isolator is a nontransmissive material in a waveguide that absorbs and does not re-emit any waves that hit it. This acts to ensure all electromagnetic energy is kept within the waveguide and cannot escape.

5a

find inductance per unit length

inner radius 1 mm
outer radius 3 mm

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

Inductance

$$\frac{1}{2\pi} \ln\left(\frac{3\text{mm}}{1\text{mm}}\right) = 0.175 \text{ nH/m}$$

assume μd is 1 $\mu d = 1$

Question No.

Examiner Only

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