



Electric field
perpendicular
stated
id
id and
field.

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 the book in half and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either read your script or have it typed and the expense of typing is 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)

PLP

$\frac{83}{100}$

~~Her~~

1a Electromagnetic waves have a electric field and magnetic field that are perpendicular and the wave propagates transversely. Stated by Faraday's law, the electric field induces the magnetic field and the magnetic field induces the electric field. Hence, the wave self propagates as no external drive is needed.

1b $P(-0.2, 0, -2.3)$
 $Q(0.2, 0.1, -2.5)$

$$\vec{E} = \frac{Q_1}{4\pi\epsilon_0 d^2} \vec{a}_1$$

$$Q_1 = 5 \times 10^{-9}$$

$$\epsilon_0 = 8.8 \times 10^{-12}$$

$$d = \sqrt{(-0.2 - 0.2)^2 + (0.1 - 0)^2 + (-2.5 - 2.3)^2}$$

$$d = 4.5826 \text{ m}$$

$$\vec{D}(0.4, 0.1, -0.2) \quad \vec{a} = \frac{\vec{D}}{d}$$

$$\vec{E} = \frac{5 \times 10^{-9}}{4\pi \times 8.8 \times 10^{-12} \times (4.5826)^2} \times \frac{\vec{D}}{4.5826}$$

$$\vec{E} = 469.83 \times 10^{-9} (0.4, 0.1, -0.2)$$

$$\vec{E} = 469.84 (0.4, 0.1, -0.2)$$

$$\vec{E} = (187.94, 46.98, -93.97) \text{ J/m}$$

1c The main difference between ionising and non-ionising radiation is that ionising can cause mutations / damage to cells which is harmful to living things. Ionising radiation typically has a larger wavelength (x-ray) and higher frequencies such as x-ray. Whereas non-ionising radiation has a smaller wavelength and higher frequency such as radio waves. Ionising radiation is used

1c extensively in ~~medical~~ medicine for imaging and ~~treat~~ cancer. Non-ionising radiation is used for AM and FM radio to transmit data, audio, or video.

2a Electromagnetic waves have a electric and magnetic field that are in phase and perpendicular.

- The wave propagates in a transverse manner.
- EM waves do not need a medium to propagate in (Self-propagating).
- EM waves can be diffracted, refracted, dispersed, interfered, reflected and absorbed.

2bi The electric flux (ϕ) is proportional to the ~~surf~~ closed surface charge.

$$\phi = \frac{Q}{\epsilon_0}$$

2bii The presence of a magnetic field induces a current resulting in a electric field perpendicular and phase shifted to be induced.

$$2c F = \frac{\mu I_1 I_2 L}{2\pi d}$$

$$\mu = 4\pi \times 10^{-7}$$

$$I_1 = 3A \quad I_2 = 6A$$

$$d = 0.05 \quad L = 1$$

$$F = \frac{4\pi \times 10^{-7} \times 3 \times 6 \times 1}{2\pi \times 0.05}$$

$$F = 7.2 \times 10^{-5} N$$

$$= 72 \mu N$$

2 d $NA = 0.48$ $n_2 = 1.45$

$$NA^2 = n_1^2 - n_2^2 \quad n_1 = \sqrt{NA^2 + n_2^2} \quad n_1 = 1.53$$

Refractive
Index of
Core

$$\phi_a = \sin^{-1}(NA) \quad \phi_a = \sin^{-1}(0.48) = 28.69^\circ$$

Acceptance
angle

3a i $m=1$ $n=0$ $a=0.04$ $b=0.02$

$$f_c = \frac{c}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$f_c = \frac{3 \times 10^8}{2} \sqrt{\left(\frac{1}{0.04}\right)^2}$$

$$f_c = 3.75 \text{ GHz}$$

3a ii $\lambda_c = \frac{c}{f_c} \quad \lambda_c = \frac{3 \times 10^8}{3.75 \times 10^9} \quad \lambda_c = 0.08 \text{ m} = 8 \text{ cm}$

3b Signal modulation is the process of encoding a carrier signal with a message (modulating) signal by varying the amplitude, frequency, or phase.

This is beneficial as it allows for RF communication over longer ranges with less interference. Additionally, it enables data, audio, or video to be encoded within the signal/message being transmitted.

3c A phased array system has multiple antennas to transmit and receive from. This coupled with digital signal processing techniques, can enable beam forming, higher resolution returns, and real-time results when compared to a single antenna system. However, this does come with a higher level

3c OS system complexity, cost, and power consumption. Phased array systems are typically used in commercial aviation tracking radars as well as military tracking/detection systems.

3d $c = f\lambda$ $f = \frac{c}{\lambda}$ $f = \frac{3 \times 10^8}{800 \times 10^{-9}}$ $f = 375 \times 10^{14} \text{ Hz}$
 $= 375 \text{ THz}$

4a $v = \frac{\lambda f_{dp}}{2}$ $\frac{2v}{\lambda} = f_{dp}$

Q3 = 23

$f_{dp} = \frac{2 \times 1000}{2 \times 10^{-9}}$ $f_{dp} = 1 \times 10^{-6} \text{ Hz}$
 $= 1 \mu\text{Hz}$

4b $d = \frac{S \times k}{2}$ $d = \frac{3 \times 10^6 \times 2 \times 10^{-6}}{2}$ $d = 300 \text{ m}$

4c $f = 5 \times 10^9$ $P = 150 \times 10^3$ $G_t = 25$ $G_r = 20$
 $RCS = 8 \text{ m}^2$ $\text{range} = 20 \times 10^3$ $L = 1.5$

4ci $c = f\lambda$ $\lambda = \frac{c}{f}$ $\lambda = \frac{3 \times 10^8}{5 \times 10^9}$ $\lambda = 0.06 \text{ m}$
 $= 6 \text{ cm}$

4cii $P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4 L}$

$P_r = \frac{150 \times 10^3 \times 25 \times 20 \times (0.06)^2 \times 8}{(4\pi)^3 \times (20 \times 10^3)^4 \times 1.5}$

$P_r = 4.54 \times 10^{-15} \text{ W}$

4d The 4 port magic tee sits within a microwave system to take an input and provide 3 variations of the wave as output. These outputs are:

- Half the ~~same~~ wavelength $\rightarrow$
- Double the wavelength
- A 90° phase shifted wavelength.

If the input wave is on one of the ports described above, it will be treated as being equal to that port's purpose.

This is useful to have in a microwave communication system so a sensitive receiver circuit is ~~not damaged~~ as well as providing multiple variations of the input wave that can be used later within the system.

$Q_4 = 16$