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12 Pages

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 and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either reject illegible script or have it typed and the expense of typing charged to the candidate.
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1	Student Number	2306891
2	Title of Examination Paper	Electromagnetic Radiation
3	Module Code	ALPC5004
4	Date and Time of Examination	08.05.25 15:00
5	Examination Venue	360
6	Seat Number	50
7	Number of Answer Books handed in	1

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

Q1a. The 2 equations that explain why electromagnetic waves do not need a medium to propagate are Maxwell's equation and Faraday's Law.

Faraday's Law states that an oscillating magnetic field will induce an appropriate oscillating electric field. Then Ampere's Maxwell's law states that an oscillating electric field will induce a magnetic field too. So therefore as long as there is either an oscillating electric or magnetic field it will allow the wave to self propagate through free space.

Q1b. $\vec{F} = \frac{Q_1 Q_2}{4\pi\epsilon_0 d^2} \hat{a}_{12}$

$P = (-0.2, 0, -2.3)$

$Q = (0.2, 0.1, -2.5)$

$$\begin{matrix} x \\ y \\ z \end{matrix} \begin{pmatrix} -0.2 \\ 0 \\ -2.3 \end{pmatrix} \rightarrow \begin{pmatrix} 0.2 \\ 0.1 \\ -2.5 \end{pmatrix} = \begin{pmatrix} -0.4 \\ -0.1 \\ 0.2 \end{pmatrix}$$

$$\vec{F} = \frac{5 \times 10^{-9}}{4\pi \times 8.854 \times 10^{-12} \times 0.3^2} = -499.319$$

$\vec{F} = -499.319 \hat{a}_{12}$

$\vec{F} = -499.319 (-0.4, -0.1, 0.2)$

$$\begin{aligned} \vec{F} = \quad x &= 199.727 \text{ N/m} \\ y &= 49.932 \text{ N/m} \\ z &= -99.864 \text{ N/m} \end{aligned}$$

Q1c. Non-ionising electromagnetic radiation includes radio waves and microwaves. These do not damage cells in the body if exposed to it. This type of electromagnetic radiation ranges from 300 Hz to 300 GHz. It is used in communications systems, infrastructure and RADAR. The wavelengths of non-ionising radiation can range from 100s of km's to millimetres.

Ionising radiation is mostly above visible light in the electromagnetic spectrum. These include UV, X-ray and gamma rays. In society this form of radiation is used for imaging of the body and fighting cancer to name a few. Ionising radiation means it breaks down the human body's cells and harms us. Frequencies are in the Terahertz range and above for most of the radiation. With wavelengths starting at the nanometre scale. It can also be used in construction for structural checks on buildings.

Q2c. The fundamentals of electromagnetic waves include:

- They travel at 3×10^8 m/s in free space.
- They are linked using $C = f\lambda$ equation denoting the speed of light, frequency and wavelength.
- They are self-propagating thanks to Ampere-Maxwell's and Faraday's laws.
- A magnetic field will induce a electric field.
- An electric field will induce a magnetic field.
- Data can be encoded into them thanks to modulation.

Q2bi. Gauss Law of electricity states that when there is more surface current on the an object. The flux density within the electric field is stronger.

2

Q2bii. Faradays Law states that an oscillating magnetic field will induce an oscillating electric field tangential to it.

2

Q2c.
$$F = \frac{\mu I_1 I_2 L}{2\pi d}$$

2

2

$$F = \frac{(4\pi \times 10^{-7}) \times 3 \times 6}{2\pi \times 0.05} = 7.2 \times 10^{-5} \text{ N/m}$$

2

Q2d.
$$NA = \sqrt{N_1^2 - N_2^2}$$

$$\phi_9 = \sin^{-1} \left(\frac{NA}{n_0} \right)$$

$$0.48 = \sqrt{N_1^2 - 1.45^2}$$

$$N_1 = \sqrt{0.48^2 + 1.45^2}$$

$$N_1 = 1.527$$

$$\phi_9 = \sin^{-1} \left(\frac{0.48}{1} \right) = 28.69^\circ$$

4

3

Q2 = (21)

Q34i $f_c = \frac{c}{2} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2}$

T.E. 10
 $f_c = \frac{3 \times 10^9}{2} \sqrt{\left(\frac{1}{0.02}\right)^2 + \left(\frac{0.02}{1}\right)^2} =$

$f_c = \frac{3 \times 10^9}{2} \times \sqrt{\left(\frac{1}{0.02}\right)^2 + \left(\frac{0}{0.02}\right)^2} = 3750000000 \text{ Hz}$

$f_c = 3.75 \text{ GHz}$

Q34ii $\lambda = c/f$

$\lambda = \frac{3 \times 10^9}{3.75 \text{ GHz}} = 0.08 \text{ m}$

Q3c A phased array system is a system with a phased array antenna attached. The phased array antenna allows for real complex control of the output of the system.

These could include:

- MIMO (multiple input multiple output) allowing the system to communicate with multiple devices all at once.
- Beam forming: using destructive and constructive interference to steer the output towards a selected device, modern telecomm systems use this technique.
- Ability to transmit and receive at the same time.

All these things simply aren't possible with a single antenna as all these things would have to be completed sequentially not in parallel like in a phased array system.

Q34. $c = f\lambda$

$$f = \frac{c}{\lambda}$$

$$f = \frac{3 \times 10^8}{900 \times 10^{-9}} = 3.75 \times 10^{14} \text{ Hz} = \cancel{375 \text{ THz}} \quad 375 \text{ THz}$$

$$Q3 = 11$$

Q43. $V = \frac{\lambda f d_f}{2}$

$$f d_f = \frac{\lambda}{2v}$$

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3 \times 10^8}{2 \times 10^9} = 0.15$$

$$f d_f = \frac{0.15}{2 \times 10^{-6}} = 7.5 \times 10^5 \text{ Hz}$$

Q46. $S = D/T$

$$\cancel{D = S} \quad D = S \times T$$

$$\cancel{D = \frac{3 \times 10^8}{2 \times 10^{-6}}} \quad D = 3 \times 10^8 \times 2 \times 10^{-7} = 600 \text{ m}$$

$$\frac{600}{2} = 300 \text{ m}$$

$$Q47. P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 R^2 L}$$

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



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

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

$P_r = \frac{150 \times 10^3 \times 28 \times 20 \times 0.06^2 \times 8}{(4\pi)^3 \times 20^4 \times 1.5} = 4.535 \times 10^{-5} \text{ W}$

4d The 4 port magic Tee is a splitter for RF signals.

If a signal ~~of the~~ is fed through port 1 and port 2. The sum will exit the H arm (port 3) and 0 will be put through the E arm (port 4).

If a signal is fed through port 3, the H arm, it will be split equally out port 1 and 2 and 0 will be output from port 4, the E arm.

If a signal is fed into the E arm, port 4. The output will come out port 3, H arm and ~~the~~ difference out of port 1 and 2.

It allows for ~~trans~~ transmit and receive elements to be accurately ~~power~~ moved around a system.



Question No.

Examiner Only

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