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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 Examiners can either ignore illegible answers 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.**

1	Student Number	2318704
2	Title of Examination Paper	ELECTROMAGNETIC RADIATION
3	Module Code	ACDCS009
4	Date and Time of Examination	8/5/25 1500
5	Examination Venue	310
6	Seat Number	21
7	Number of Answer Books handed in	~~4~~ 1.

[illegible]
$$\frac{65}{106}$$

~~Ac.~~

PLP

- 1a. Radar freq: 2942
Velocity: 1000 m/s

$$c = f\lambda$$

$$V = \frac{\lambda f_{dp}}{2}$$

$$3E^8 = 2E^9 \times \lambda$$

$$1000 = \frac{2 \times f_{dp}}{2}$$

$$\lambda = \frac{3E^8}{2E^9} \quad \lambda = 0.15$$

$$f_{dp} = \frac{2000}{0.15}$$

$$f_{dp} = 13.3 \text{ KHz}$$

- b. Signal modulation is where a carrier signal, is changed in amplitude, phase or frequency depending on the message signal to be transmitted. It enhances line of sight communications by reducing noise (interference), increase security and strength of signal/greater distance.

c. $\lambda = 800 \text{ nm}$

$$f = ?$$

$$c = f\lambda$$

$$3E^8 = f \times 800E^{-9}$$

$$f = \frac{3E^8}{800E^{-9}}$$

$$f = 3.75E^{14} \text{ Hz}$$

d. $\Delta t = \frac{2R}{c}$

$$2E^{-6} = \frac{2R}{3E^8}$$

$$R = \frac{2E^{-6} \times 3E^8}{2}$$

$$= 300 \text{ m}$$

e. $\phi_c = \sin^{-1} \left(\frac{n_2}{n_1} \right)$

$$\phi_c = \sin^{-1} \left(\frac{1.5}{1.6} \right)$$

$$\phi_c = \sin^{-1}(0.9375) \quad \phi_c = 69.6^\circ \quad 1 \text{ d.p.}$$

f. Electromagnetic waves propagate in free space:

- at the speed of Light in a vacuum (3×10^8)
- Electric and Magnetic field is transverse to the direction of propagation.
- Does not require a medium.
- Can be polarised
-

2a. i. Passive radar homing:

- Does not contain a transmitter, only a receiver within missile.
- Detects signal being transmitted from the target and guides towards.
- Difficult to jam with ECM.

ii. Active radar homing:

- missile has both transmitter and receiver, and does not require platform (Aircraft) radar for guidance.
- Platform normally provides target reference and then missile will use active radar homing in final phase.
- fire and forget

b. 200 MHz

0.15 λ element + reflector

0.2 λ Element + director

$$L = \frac{\lambda}{10}$$

$$L = \frac{1.5}{10}$$

$$L = 0.15 \text{ m.}$$

$$c = f \lambda$$

$$3 \times 10^8 = 200 \times 10^6 \times \lambda$$

$$\lambda = 1.5 \text{ m}$$

- c. if you were to point your thumb up, your forefinger forward and your middle finger ~~go to both~~ ~~your~~:
- thumb would be the direction of propagation
 - forefinger would be the direction of the magnetic field
 - and your middle finger would be the direction of the electric field.

It demonstrates that the electric and magnetic fields are transverse to the direction of propagation.

3a. $\begin{array}{|c|} \hline 2\text{cm} \\ \hline \end{array} \begin{array}{|c|} \hline 4\text{cm} \\ \hline \end{array} \text{TE}_{10}$

$$\begin{aligned} \text{i) } f_c &= \frac{c}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \\ &= \frac{3 \times 10^8}{2} \times \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{0}{4}\right)^2} \\ &= \frac{3 \times 10^8}{2} \times \sqrt{\left(\frac{1}{2}\right)^2} \\ &= 1.5 \times 10^8 \times 0.25 \end{aligned}$$

$$f_c = 75 \text{ MHz}$$

$$\begin{aligned} \text{ii) } \lambda_c &= \frac{c}{f_c} \\ \lambda_c &= \frac{3 \times 10^8}{75 \times 10^6} \\ \lambda_c &= 4 \text{ m} \end{aligned}$$

3b. $NA = 0.48$
 $n_1 \text{ Index} = 1.45$

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

$$0.48 = \sqrt{1.45^2 - n_2^2}$$

$$0.48^2 = 1.45^2 - n_2^2$$

$$n_2^2 = 1.45^2 - 0.48^2$$

$$= 1.87 \text{ 2dp.}$$

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

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

$$= \sin^{-1}(0.48)$$

$$\theta_a = \underline{28.69^\circ} \text{ 2dp}$$

c. Transverse Electric Mode (TE) Mode:

- Electric field is transverse to the direction of propagation.
- Magnetic field is in the direction of propagation.

Transverse Magnetic (TM) Mode:

- Magnetic field is transverse to the direction of propagation.
- Electric field is in the direction of propagation.

d. Isolator stops reflection and prevents equipment damage

23 = (3)

4a $Q_1 = -20 \mu\text{C}$ at $A = (-5, 4, 6)$
 $Q_2 = 40 \mu\text{C}$ at $B = (4, 8, -2)$

$$\vec{A} = -5\vec{a}_x + 4\vec{a}_y + 6\vec{a}_z$$

$$\vec{B} = 4\vec{a}_x + 8\vec{a}_y - 2\vec{a}_z$$

$$\vec{AB} = \vec{B} - \vec{A} = (4 - (-5))\vec{a}_x + (8 - 4)\vec{a}_y + ((-2) - 6)\vec{a}_z$$

$$= 9\vec{a}_x + 4\vec{a}_y - 8\vec{a}_z$$

$$|\vec{AB}| = \sqrt{9^2 + 4^2 + (-8)^2}$$

$$= 12.69 \quad 2\text{dp.}$$

$$\vec{a}_{AB} = \frac{\vec{AB}}{|\vec{AB}|}$$

$$= \frac{9\vec{a}_x + 4\vec{a}_y - 8\vec{a}_z}{12.69}$$

$$= 0.709\vec{a}_x + 0.315\vec{a}_y - 0.630\vec{a}_z \quad (3\text{d.p.})$$

$$|\vec{a}_{AB}| = \sqrt{0.709^2 + 0.315^2 - 0.630^2}$$

$$0.00000020$$

$$= \sqrt{0.205006}$$

$$= 0.453 \quad 3\text{dp}$$

$$\vec{F} = \frac{Q_1 Q_2}{4\pi\epsilon_0 d^2} \vec{a}_{AB}$$

$$= \frac{-20 \times 10^{-6} \times 40 \times 10^{-6}}{4 \times \pi \times 8.854 \times 10^{-12} \times 0.453^2} \times (0.709\vec{a}_x + 0.315\vec{a}_y - 0.630\vec{a}_z)$$

$$\frac{-8 \times 10^{-10}}{2.283 \times 10^{-11}} \times (0.709\vec{a}_x + 0.315\vec{a}_y - 0.630\vec{a}_z)$$

$$-35.04 \quad (2\text{dp}) \times (0.709\vec{a}_x + 0.315\vec{a}_y - 0.630\vec{a}_z)$$

$$= -24.1\vec{a}_x - 34.9\vec{a}_y + 22.1\vec{a}_z$$

4.b. A frequency modulated continuous wave radar emits and receives modulated frequency that allows it to detect targets velocity (relative) and distance.

Q4 = (14)



Question No.

Examiner Only

