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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, sign and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either have the 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.**

1	Student Number	2309075
2	Title of Examination Paper	Electromagnetic radiation
3	Module Code	ACDC5009
4	Date and Time of Examination	08/05/2025 15:00
5	Examination Venue	UWTSD waterfront 310
6	Seat Number	14
7	Number of Answer Books handed in	1

[illegible]
$$\frac{98}{100}$$

~~He~~

pl 2

$$1) a) f_{dp} = f_c - f_e \quad v = \frac{x f_{dp}}{2}$$

$$f_e = 2 \times 10^9$$

$$c = x f$$

$$(3 \times 10^8) \div (2 \times 10^9) = 0.15$$

$$0.15m = x$$

$$1000 = \frac{0.15 f_{dp}}{2}$$

$$2000 = 0.15 f_{dp}$$

$$13333.33 \text{ Hz} = f_{dp}$$

$$1.33 \times 10^4 \text{ Hz} = f_{dp}$$

b) Signal modulation involves combining a low frequency message signal with a high frequency carrier signal. There are three main types of modulation in RF communication. These are Amplitude modulation (AM), Frequency modulation (FM) and Phase modulation (PM). ~~Amplitude~~ AM involves altering the carrier signal based on the message signal amplitude. FM involves altering the carrier signal based on the message signal frequency. PM involves altering the carrier signal based on the phase of the message signal. The benefits of modulation include lower rates of ~~attenuation~~ allowing for greater signal ranges, as well

as allowing radio ~~users~~ ^{users} to tune into specific frequencies (based on the carrier signal frequency).

c) $c = \lambda f$

$$3 \times 10^8 = (800 \times 10^{-9}) f$$

$$f = 3.75 \times 10^{14} \text{ Hz}$$

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

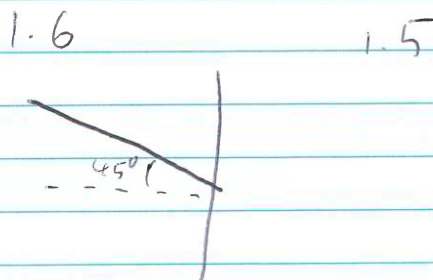
$$2 \times 10^{-6} = \frac{2R}{3 \times 10^8}$$

$$600 = 2R$$

$$300 = R$$

$$R = 300 \text{ m}$$

e)

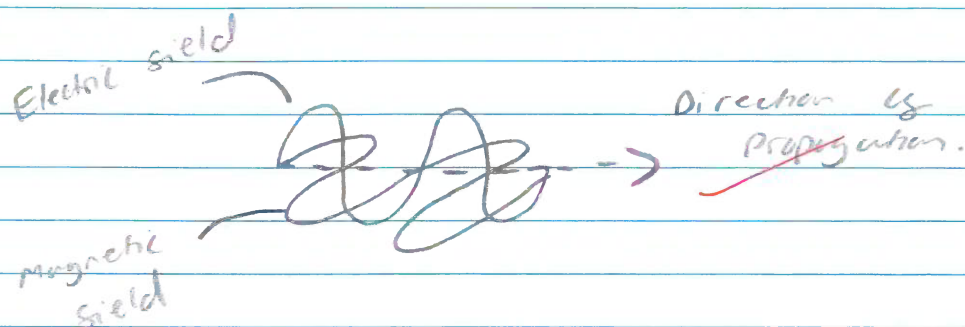


$$\phi_c = \sin^{-1} \left(\frac{n_2}{n_1} \right)$$

$$\sin^{-1} \left(\frac{1.5}{1.6} \right) = 69.64^\circ$$

$$\phi_c = 69.64^\circ$$

8) Electromagnetic waves are transverse waves comprised of both an electric field and a magnetic field. These two fields are perpendicular to each other, as well as the direction of propagation.



EM waves are self-inductively based on Faraday's Law and Ampere - Maxwell's Law.

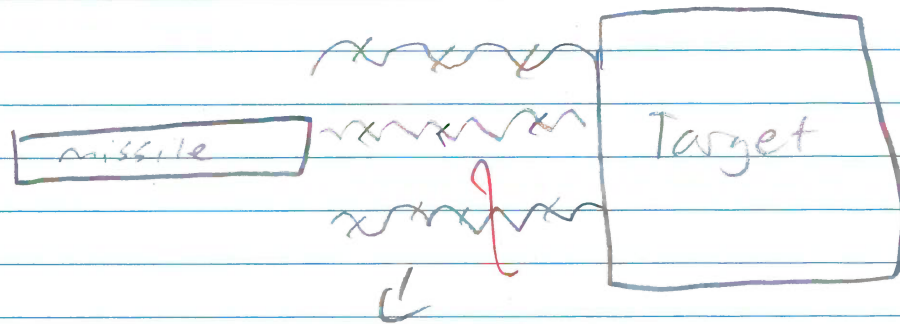
Faraday's Law - A changing magnetic field induces an electric field.

~~Maxwell's~~ Ampere - Maxwell's Law - A changing electric field induces a magnetic field.

$$\frac{28}{30}$$

$$Q_1 = 24$$

2) a) i) Passive radar homing involves a missile locking onto a targets ^{radio} emissions instead of relying on transmitting its own and gathering reflections. This makes it ~~impossible~~ hard to jam the missile radar as it will travel to ~~any~~ jamming signal attempted.

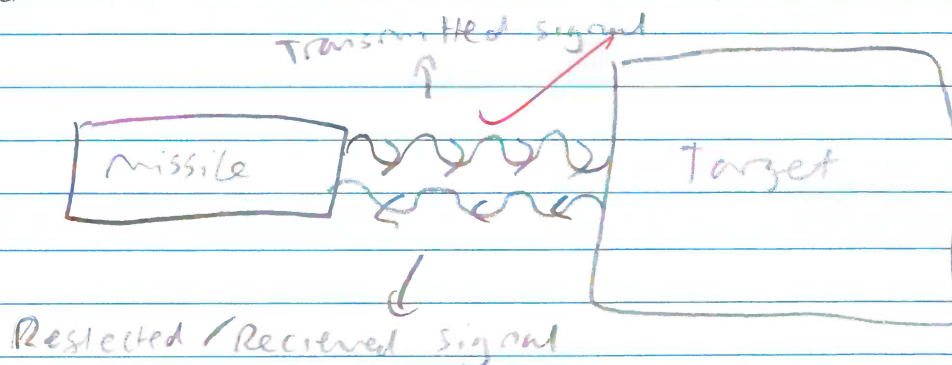


Even signal emissions provided by the target and locked onto.

4+1
✓

(ii) Active radar homing involves a missile that has its own onboard transmitting radar. It transmits electromagnetic waves and also receives ^{their} ~~from~~ ^{reflections} to calculate the targets speed, position and distance. This allows the user to give and target as the onboard radar is the only radar required. It also allows for a larger range due to the onboard radar being used for target detection. However, this type of missile can be jammed if ~~counter~~ measures are not accurately in place.

missile counter



4
✓

1
✓

b)

Reflector 5% longer than driven element
 Director 5% shorter than driven element

Driven
element

$$L = \frac{\lambda}{2}$$

$$C = f \lambda$$

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

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

$$L = \frac{1.5}{2}$$

$$L = 0.75 \text{ m}$$

The length of the driven element is 0.75m.

$$1.5 \times 0.15 = 0.225 \text{ m}$$

The distance between the driven element and the reflector is 0.225m.

$$1.5 \times 0.2 = 0.3 \text{ m}$$

The distance between the driven element and the director is 0.3m.

$$0.75 \times 1.05 = 0.7875 \text{ m}$$

The length of the reflector is 0.7875m .

$$0.75 \times 0.95 = 0.7125\text{m}$$

The length of the director is 0.7125m .

(c) The right hand rule ^{describes} ~~explains~~ the direction of EM wave propagation and direction of field components. When extending the thumb, forefinger and middle finger perpendicular to each other. The thumb represents EM wave direction of propagation. The forefinger represents electric field direction. ~~the~~ The middle finger ~~represents~~ represents magnetic field direction.

Q2 = 25

3) a) i)

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

$$a = 4 \times 10^{-2} \text{ m} \quad b = 2 \times 10^{-2} \text{ m}$$

$$m = 1$$

$$n = 0$$

$$\frac{3 \times 10^8}{2} \sqrt{\left(\frac{1}{4 \times 10^{-2}}\right)^2 + \left(\frac{0}{2 \times 10^{-2}}\right)^2}$$

$$= 3.75 \times 10^9 \text{ Hz}$$

$$= 3.75 \text{ GHz}$$

ii)

$$c = f \lambda$$

$$3 \times 10^8 = (3.75 \times 10^9) \lambda$$

$$\lambda = 0.08 \text{ m}$$

b)

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

$$0.48 = \sqrt{n_1^2 - 1.45^2}$$

$$0.2304 = n_1^2 - 2.1025$$

$$2.3329 = n_1^2$$

$$1.53 = n_1$$

1.53 is the refractive index of the core

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

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

$$\phi_a = 28.69^\circ$$

The acceptance angle is 28.69° .

c) TE mode is transverse electric mode.
The electric field is perpendicular to wave propagation. The magnetic field shows some parallel components to wave propagation.

TM mode is transverse magnetic mode.
The magnetic field is perpendicular to wave propagation. The Electric field shows some parallel components to wave propagation.

d) An isolator is a two port microwave device used to allow signals to pass in one direction but be blocked in the opposing direction. This helps remove unwanted reflections which can damage sensitive pieces of equipment such as transmitters.

$$4) a) Q_1 = -20 \text{ nC} \quad (-5, 4, 6)$$

$$Q_2 = 40 \text{ nC} \quad (4, 8, -2)$$

$$(4 - -5) + (8 - 4) + (-2 - 6)$$

$$\vec{AB} = (9, 4, -8)$$

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

$$= \sqrt{161}$$

$$\frac{\vec{AB}}{|\vec{AB}|} = 0.709 \vec{a}_x + 0.315 \vec{a}_y - 0.630 \vec{a}_z$$

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

$$\epsilon_0 = 8.854 \times 10^{-12}$$

$$\frac{(-20 \times 10^{-6})(40 \times 10^{-6})}{4\pi(8.854 \times 10^{-12})(\sqrt{161})^2}$$

$$= -0.04466 \text{ N}$$

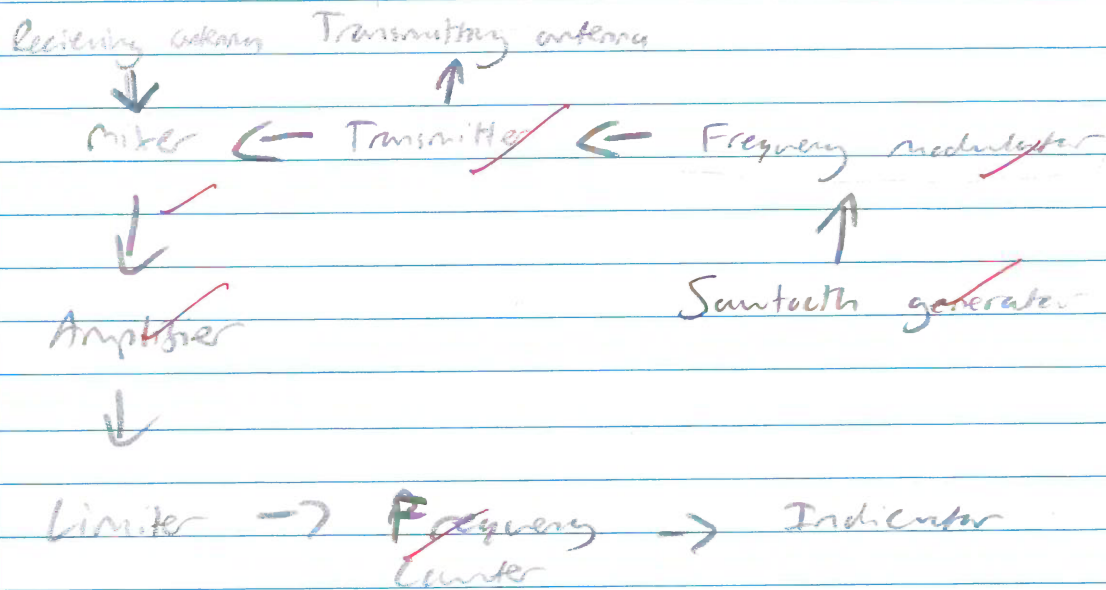
$$= -0.04466 \times (0.709 \vec{a}_x + 0.315 \vec{a}_y - 0.630 \vec{a}_z)$$

$$= -0.032 \vec{a}_x \text{ N} - 0.014 \vec{a}_y \text{ N} + 0.028 \vec{a}_z \text{ N}$$

$$\sqrt{(-0.032)^2 + (-0.014)^2 + (0.028)^2} = 0.04466 \text{ N}$$



b) Frequency modulated continuous wave radar works by continuously transmitting frequency modulated waves and receiving reflections. Frequency modulated being the frequency of the transmitted signal is altered for radar purposes. A flow chart can be seen below.



A FMCW radar works by first producing a sawtooth signal. This signal is then frequency modulated where it is passed into the transmitter, converting the electric signals into EM waves where it is passed to the transmitting antenna to send the signal out. A small amount of the transmitter signal is also sent to the mixer, which also receives a signal from the receiving antenna, picking up any reflections. This mixed signal is amplified to increase its intensity. It is then limited to set a maximum voltage. This ~~is then~~ signal is passed to the frequency ~~counter~~ ^{counter} where the transmitted and received signals are

Compared and calculations, such as doppler shift are made. This is formatted for human ~~consumption~~ consumption and displayed at the ~~indicator~~.

This type of radar is useful for tracking enemy targets and providing information on their distance, speed and position.

Q4

24



Examiner Only

Question No.

Rhif y Cwestiwn

Arholwr yn unig