

able to
~~that~~
waves
~~noir~~

2

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 ignore illegible 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)

$\frac{51}{100}$

Q1 a) Electromagnetic waves are able to travel at the speed of light ~~calculated by~~ $C = f \times \lambda$. also the waves can travel in a vacuum they ~~do not~~ require a medium

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

$P \times Q = \begin{bmatrix} i & j & k \\ -0.2 & 0 & -2.3 \\ 0.2, 0.1, -2.5 \end{bmatrix}$

c) Ionising

Cancer-causing/harmful
low wavelength

MRI machines/hospitals

lower high frequency

low frequency

non ionising

Safer/
high wavelength

communications/radios

high frequency

$\phi = 7$

- 2) a)
- 1 Can be polarised
 - 2 move at the speed of light (3×10^8 m/s)
 - 3 Self propagating
 - 4 Can travel through a vacuum
 - 5 Can be refracted, diffracted, absorbed, scattered...
 - 6 has both E and B fields (electromagnetic)

$$Q \quad F = \frac{\mu_0 I_1 I_2 L}{2 \pi d}$$

$$F = \frac{(4\pi \times 10^{-7}) \times 3 \times 6}{2 \times \pi \times 0.5}$$

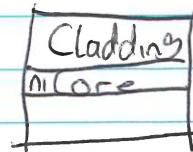
d) refractive index $= n = \frac{c}{v}$
 Acceptance angle $= \theta_a = \sin^{-1} \left(\frac{NA}{n_0} \right)$

$$NA = 0.48$$

$$n_2 = 1.45$$

$$n_0 = 1 \text{ (Air)}$$

$$n = \frac{c}{v}$$



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

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

$$1.53 = \sqrt{0.48^2 + 1.45^2}$$

$$\text{Refractive index} = 1.53$$

$$\sin^{-1} \left(\frac{NA}{n_0} \right) = 0.5^\circ$$

$$\sin^{-1} \left(\frac{0.48}{1} \right) = 0.5^\circ$$

Q2 = 13

3)a) i) Cut of frequency = $f_c = \frac{c}{\lambda} = \frac{c}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

Where c = Speed of light
 m, n are the modes 10 being highest

a are width 4cm

b are height 2cm

So $f_c = \frac{3 \times 10^8}{2} \sqrt{\left(\frac{10}{0.4}\right)^2 + \left(\frac{10}{0.2}\right)^2}$
 $= 1 \text{ Hz}$

ii) $\lambda_c = \frac{c}{f_c} = \frac{3 \times 10^8}{1} = 300000000$
 Cut of wavelength

b) Signal modulation is the changing of all key components in a signal or carrier frequency.

- less signal interference
- smaller antennas
- multiple transmissions due to signal multiplexing
- harder to interfere or jam

c) a phased array is a collection of antennas in a circular pattern that combine to become omnidirectional.

- benefits over single antenna (dipole)

- 1) - Can Tx and Rx at the same time
- 2) - allows for precise detection
- 3) - positive / constructive interference
- 4) - wider applications
- 5) - larger field pattern
- 6) - ~~more~~ can become highly directional

d) $c = f \lambda$

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

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

$$\frac{3 \times 10^8}{800 \times 10^{-9}} = 375 \text{ THz}$$

$$Q_3 = 14$$

$$Q4) a) v = \frac{\lambda f_{\text{dop}}}{2}$$

$$c = f \lambda$$

for f_{dop}

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

$$f_{\text{dop}} = \frac{2v}{\lambda}$$

$$\frac{3 \times 10^8}{3 \times 10^9} = \frac{3}{20}$$

$$2 \text{ GHz} = 2000000000$$

$$2 \times 10^9$$

$$\frac{2 \times 1000}{(\frac{3}{20})} = \frac{40000}{3} \text{ or}$$

$$13.33 \text{ kHz}$$

$$13333.33$$

$$b) \Delta t = \frac{2R}{c} \text{ or } D = S \times T$$

$$\text{time is } 2 \times 10^{-6} / 2 = 1 \times 10^{-6}$$

$$\text{Speed is } 3 \times 10^8$$

$$\text{Distance} = 1 \times 10^{-6} \times 3 \times 10^8 = 300 \text{ m}$$

$$c = f \lambda$$

$$3 \times 10^8 = 5 \times 10^9 = \lambda$$

$$\lambda = \frac{c}{f} = \frac{3}{50} \text{ or } 0.06 \text{ m}$$

ii) radar range equation is

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

Where

P_t is Power Transmitted = 150 kW

G_t is Gain on transmit = 25

G_r is Gain or receive = 20

λ is wavelength = 0.06

σ is radar cross section = 8 m^2

R is range = 20 km

L is System loss = 1.5

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

$$3750000 \times 0.072 \times 8$$

$$1984 \times 1.6 \times 10^{17} \times 1.5$$

$$= 4.536 \text{ fW}$$

$$\frac{2160000}{4.7616 \times 10^{20}}$$

Q4 = 17



Question No.

Examiner Only

