

oscillating

12 Pages

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7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
Q1	25 ✓
Q2	25 ✓
Q3	25 ✓
Q4	24 ✓
Total	99

99
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100

~~MC~~

PLP

1.

a. Electromagnetic waves consist of oscillating electric and magnetic fields. ✓

Faraday's law states that a time varying magnetic field induces an electric field. ✓

Ampere-Maxwell's law states that a time varying electric field induces a magnetic field. ✓
This means in an EM wave the oscillating electric field induces the magnetic field and the oscillating magnetic field induces the electric field. ✓

The interplay between the two fields in this way result in EM waves being self propagating. ✓

b. $P(-0.2, 0, -2.3)m$ $Q(0.2, 0.1, -2.5)m$. ✓

$$\vec{r} = \vec{QP} = \langle -0.2, 0, -2.3 \rangle - \langle 0.2, 0.1, -2.5 \rangle.$$

$$= \langle -0.4, -0.1, 0.2 \rangle m. ✓$$

$$|\vec{r}| = \sqrt{(-0.4)^2 + (-0.1)^2 + (0.2)^2}$$

$$= \frac{\sqrt{21}}{10} = 0.458 m ✓$$

$$\vec{E} = \frac{q}{4\pi\epsilon_0 |\vec{r}|^3} \vec{r}$$

$$q = +5nC$$

$$|\vec{r}| = 0.458$$

$$\vec{E} = \frac{5 \times 10^{-9}}{4\pi \times 8.85 \times 10^{-12} \times 0.458^3} \vec{r} ✓$$

$$\vec{r} = \langle -0.4, -0.1, 0.2 \rangle$$

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

$$= 466.97 \cdot \langle -0.4, -0.1, 0.2 \rangle V/m^2 ✓$$

$$\vec{E} = \langle -186.79, -46.70, 93.39 \rangle V/m^2 ✓$$

Answer given to 2 decimal places.

1

- c. Ionising radiation are EM waves that has the ability remove electrons from atoms turning them into ions. These types of EM waves are capable of causing damage to cells of living organisms. Non ionising radiation does not cause this and is safer with the primary hazard of causing heating of living organisms.

Non-ionising radiation consists of EM waves below ultraviolet radiation which are em waves with a frequency less than 790 THz or a wavelength greater than 379 nm .

Types of non-ionising radiation includes:

- Radio waves

Frequency: $< 300 \text{ GHz}$.

wavelength: $> 1 \text{ mm}$

uses: communication system.

- Micro waves: $\text{Freq: } 300 \text{ MHz} - 300 \text{ GHz}$.

wavelength: $1 \text{ mm} - 1 \text{ m}$.

uses: cooking and communication.

- Infrared

Frequency: $300 \text{ GHz} - 430 \text{ THz}$.

wavelength: $638 \text{ nm} - 1 \text{ mm}$

uses: heating and tv remotes.

- Visible light

Frequency: $430 \text{ THz} - 790 \text{ THz}$.

wavelength: $379 \text{ nm} - 700 \text{ nm}$

uses: communication and seeing.

Types of ionising radiation includes:

- Ultraviolet

Frequency:

$790\text{THz} - 330\text{PHz}$.

Wavelength:

$90\text{nm} - 700\text{nm}$.

Uses:

curing resins / tanning.

- X-Rays

Frequency:

$330\text{PH} - 30\text{EHz}$.

Wavelength:

$10\text{pm} - 90\text{nm}$

Uses:

medical applications.

- Gamma Rays

Frequency:

$> 30\text{EHz}$.

Wavelength:

$< 10\text{pm}$

Uses:

medical applications.

$Q_1 = 25$

2.

a. EM waves consist of the following properties:

- Are self propagating
- Do not require a medium
- Follows $c = f \cdot \lambda$
- Experience scattering, refraction, reflection, diffraction, dispersion and subject to interference.
- Can be polarised.
- are transverse in nature
- consist of perpendicular and in phase electric and magnetic fields.

b.

i. Gauss's law of electricity states the ~~magnetic flux~~ electric flux flowing out of a closed surface is proportional to the charge enclosed.

$$\oint \vec{E} \cdot d\vec{s} = \frac{q_{enc}}{\epsilon_0}$$

ii. Faraday's law of induction states that a time varying magnetic field induces an electric field.

$$\nabla \cdot \vec{E} = -\frac{\partial H}{\partial t}$$

2.
c.

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

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

$$\mu = 4\pi \times 10^{-7} \text{ H/m.}$$

$$I_1 = 3 \text{ A}$$

$$I_2 = 6 \text{ A.}$$

$$d = 5 \text{ cm} = 0.05 \text{ m.}$$

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

$$= 72 \mu\text{N/m}$$

2 ✓

2 ✓

2 ✓

d.

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

$$\phi_a = \arcsin\left(\frac{NA}{n_0}\right)$$

n_1 = refractive index of core

n_2 = refractive index of cladding
= 1.45.

$$NA = 0.48$$

$$NA^2 = n_1^2 - n_2^2$$

$$NA^2 + n_2^2 = n_1^2$$

acceptance angle
 $\phi_a = \arcsin\left(\frac{NA}{n_0}\right)$

$$n_0 = 1$$

$$\phi_a = \arcsin(0.48) = 28.69^\circ$$

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

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

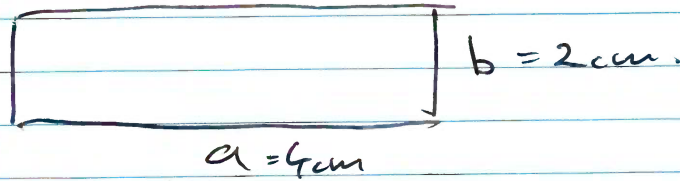
$$n_1 = 1.527 \text{ (3 d.p.)}$$

4 ✓

3 ✓

Q2 = 23

3.



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

for TE_{10} $m = 1$ $n = 0$.

$a = 0.04 \text{ m}$

$b = 0.02 \text{ m}$

$$f_c = \frac{3 \times 10^8}{2} \sqrt{\left(\frac{1}{0.04}\right)^2 + \left(\frac{0}{0.02}\right)^2}$$

$$= 3.75 \text{ GHz}$$

ii.

$$c = f\lambda$$

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

$$c = 3 \times 10^8$$

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

$$\lambda = \frac{3 \times 10^8}{3.75 \times 10^9}$$

$$= 0.08 \text{ m}$$

3.

b.

Signal modulation is the encoding of a data signal onto a carrier wave. The benefits of modulation include:

- Efficient use of the spectrum - enables a change of transmission frequency to maximise all of the spectrum
- Reduced antenna size - modulating to higher frequencies allow for antennas to be smaller.
- Reduce attenuation - a signal can be modulated to a frequency that experiences minimal attenuation
- Multiplexing - a single channel can be used to send multiple signals
- Reduce interference - can allow for frequency to be used with reduced noise and interference experienced.

c. A phased array system is a system consisting of an array of radiating antenna elements. A transmitting signal is applied to all elements but with varying phase shifts which allows for the radiation pattern of the entire array system to be controlled, enabling the beam to be steered in specific direction. Using a phased array over a single antenna allows for higher gain and more efficient transmission. However phased arrays are much more complicated with a greater number of feeds and supporting components for it to work.

3.

d-

$$c = f \cdot \lambda$$

$$c = 3 \times 10^8 \text{ m/s.}$$

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

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

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

Q3 = 25

4

/

4.
a.

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

$$f_{dp} = f_r = f_t.$$

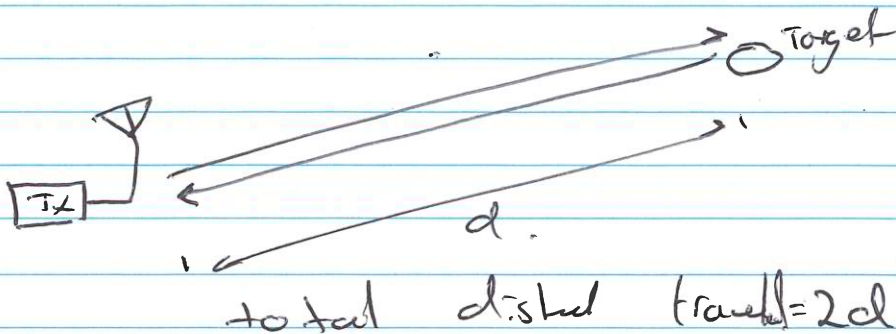
$$\frac{2V}{\lambda} = f_{dp}.$$

$$V = 1000 \text{ m/s.}$$

$$\lambda = \frac{3 \times 10^3}{2 \times 10^7} = 0.15 \text{ m.}$$

$$f_{dp} = \frac{2 \times 1000}{0.15} = 13.3 \text{ kHz.}$$

b.



$$v = \frac{d}{t}$$

$$vt = d$$

$$v = 3 \times 10^8$$

$$t = 2 \times 10^{-6}$$

$$3 \times 10^8 \times 2 \times 10^{-6} = 2d.$$

$$600 = 2d.$$

$$d = 300 \text{ m.}$$

c.

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

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

$$P_t = 150 \text{ kW}$$

$$G_t = 25$$

$$G_r = 20$$

$$\sigma = 8 \text{ m}^2$$

$$R = 70 \text{ km}$$

$$L = 1.5$$

4.

c.

$$C = f\lambda$$

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

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

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

$$P_e = 150000 \text{ W}$$

$$G_e = 25$$

$$G_r = 20$$

$$\lambda = 0.06 \text{ m}$$

$$\sigma = 8 \text{ m}^2$$

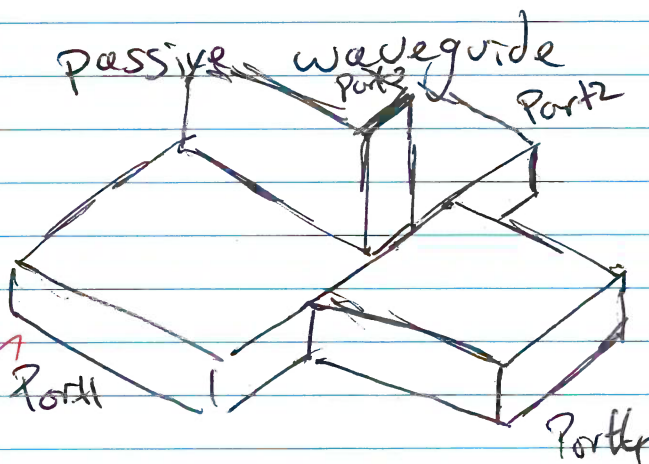
$$R = 20000 \text{ m}$$

$$L = 1.5$$

$$P_r = \frac{150000 \times 25 \times 20 \times 0.06^2 \times 8}{(4\pi)^3 \times 20000^4 \times 1.5}$$

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

- d. A magic tee is a passive waveguide device consisting of four ports. Port 1 and 2 are collinear ports. Port 3 is the difference port. Port 4 is the summing port.



A magic has 3 cases of operation

Case 1:

When equal signals are applied to ports 1 and 2, the difference is seen at port 3 (in this case no signal) and the sum is seen at port 4 (in this case double the input).

Case 2

If a signal is applied to port 4
no signal is seen at port 3 and
a signal of half the amplitude is
seen at both ports 1 and 2 which
are in phase.

Case 3

If a signal is applied to port 3
no signal is seen at port 4 and
signals of half the amplitude is
seen at ports 1 and 2 but are
 180° out of phase.

4
✓

