



Examiner Only

12 Pages

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1	Student Number	2110763
2	Title of Examination Paper	Electromagnetic Radiation
3	Module Code	ACDC5009
4	Date and Time of Examination	03/05/2023 09:00
5	Examination Venue	
6	Seat Number	002
7	Number of Answer Books handed in	

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

1)

a.) An electromagnetic wave is a transverse wave with a magnetic (H) field and an electric field (E), which are both oscillating in phase with each other.

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b.) Electromagnetic waves have a number of properties. They are self propagating, through an oscillating electric and magnetic fields which are in phase with each other but transverse at 90° . Both electric and magnetic fields ~~are~~ are in the same direction as propagation. Electromagnetic waves obey the law equation $C = f\lambda$ and travel at the speed of light in a vacuum ($3 \times 10^8 \text{ m/s}$). Finally, Electromagnetic waves ~~do~~ do not require a medium in which to propagate. Finally, EM waves can be, reflected, refracted, diffracted, scattered, and cause interference.

6

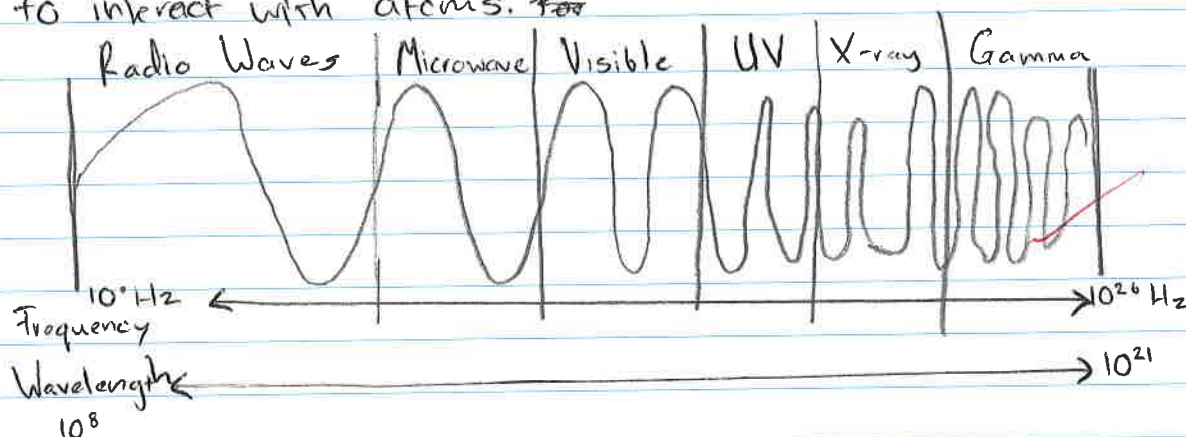
c.) An electromagnetic wave is self propagating; which is caused by the oscillations of electric and magnetic fields at 90° to each other but in phase, in the direction of propagation.

2

d.) An Electromagnetic Spectrum spans a range of frequencies from ~~0 Hz~~ to ~~300 GHz~~; in order of: radio waves, microwaves, visible light, ultraviolet, X-rays and Gamma rays. Radio waves have the lowest

10

Frequency and gamma being the highest. Radio waves span the lowest frequencies from 30Hz to 300GHz ~~and~~, examples of radio waves being AM radio (535-1608Hz) and FM radio (88-108MHz); which are both used for radio. A feature of the electromagnetic spectrum is that the frequency of the waves is inversely proportional ~~to the energy~~ and wavelength, so ~~a higher frequency~~ and ^{directly} proportional to the energy - so if the frequency is increased, the wavelength is reduced and the energy of the wave increases. At frequencies beyond ultraviolet, the electromagnetic waves become ionising, meaning they have enough energy to interact with atoms. For



- e.) In waveguides, a TE mode means that ^{only} the magnetic field is in the direction of the wave - with the electric field being perpendicular to it.

$$2 + 6 + 2 + 7 + 2 = 19$$

2.)

a.) Polarisation ~~can be~~ in the respect of magnetism can be north ~~or~~ south. An EM wave can be polarised with respect to the axis it's on. An EM wave can be polarised linearly ✓

$$\begin{aligned} b.) \quad P &= (-6, 4, 6) \\ R &= (5, 8, 2) \\ Q_1 &= -20 \times 10^{-6} \text{ C} \\ Q_2 &= 50 \times 10^{-6} \text{ C} \end{aligned}$$

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

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$$

$$d_{PR} \bar{PR} = (-6 - 5)a_x + (4 - 8)a_y + (-2 - 6)a_z$$

$$d_{PR} \bar{PR} = -11a_x - 4a_y - 8a_z$$

$$|d_{PR}| = \sqrt{(-11)^2 + (-4)^2 + (-8)^2}$$

$$|d_{PR}| = 14.177$$

$$\bar{a}_{12} = \frac{-11a_x - 4a_y - 8a_z}{14.177}$$

$$\bar{a}_{12} = -0.776a_x - 0.282a_y - 0.564a_z$$

$$F = \frac{(-20 \times 10^{-6})(50 \times 10^{-6})}{4\pi(8.854 \times 10^{-12})(14.177)^2} [-0.776a_x - 0.282a_y - 0.564a_z]$$

$$F = -0.0447 [-0.0776 a_x - 0.282 a_y - 0.964 a_z] N$$

$$Q2 \quad (+1F2+1F1) = 6$$

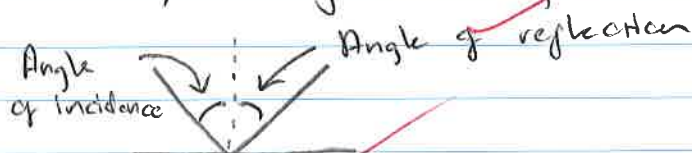
3.)

a.)

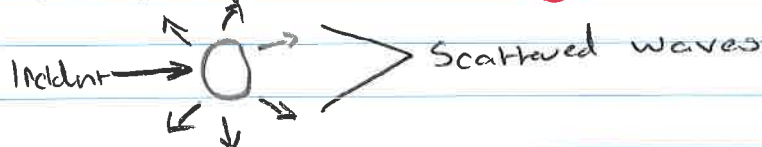
i.) Diffraction is when an incident wave is split by an object to provide coverage of the screened area.



ii.) This is when an incident wave's angle of incidence is above the critical ~~threshold~~ angle threshold, allowing the wave to reflect, at the angle of reflection, continuously along a waveguide medium.

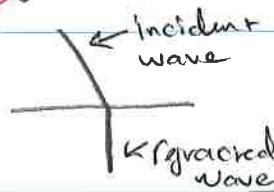


iii.) Scattering is when an incident wave interacts with a small particle, scattering the incident wave into multiple directions.

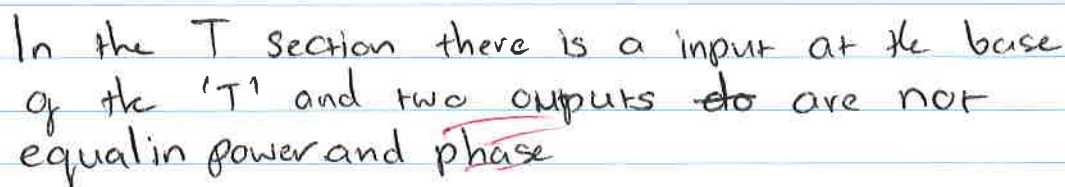


iv.) Interference is when multiple (2 or more) EM waves interact with each other, altering the properties of the wave, with respect to phase, power.

v.) This is when the wave passes through a medium of a different refractive index, changing the angle of the wave when passing through.



2



1



• Coupler



9 inputs.

Q3
 $1+2+2+2+2+2+1=12$

Final Answer ✓

4.)

$$a.) P_v = 102^2 x \sin \pi y \quad \begin{matrix} (-1 \leq x \leq 2) \\ (0 \leq y \leq 1) \\ (3 \leq z \leq 3.6) \end{matrix}$$

$$10 \left[\left[\frac{z^3}{3} \right]_3^{3.6} \left[\frac{x^2}{2} \right]_{-1}^2 \left[\frac{-\cos \pi y}{\pi} \right]_0^1 \right]$$

$$10 \left[\left[\frac{3.6^3}{3} - \frac{3^3}{3} \right] \left[\frac{2^2}{2} - \frac{-1^2}{2} \right] \left[\frac{-\cos \pi y}{\pi} + \frac{\cos 0}{\pi} \right] \right]$$

$$10 \left[\left[\frac{3.6^3}{3} - 9 \right] [1.5] \left[\frac{-\cos \pi y}{\pi} + \frac{1}{\pi} \right] \right]$$

$$P_v = 62.57 C$$

$$b.) \sin^{-1} \left(\frac{1.47}{1.5} \right) = 78.52^\circ$$

Critical Angle = ϕ_c

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

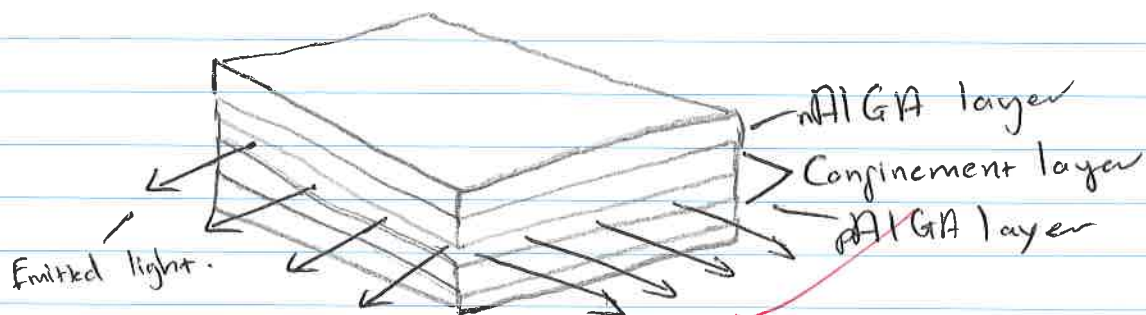
$$\phi_c = 78.52^\circ$$

Acceptance Angle = ϕ_a

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

$$NA = (n_2^2 - n_1^2)^{1/2}$$

c.)



A laser (Light Amplification by Stimulated Emission of radiation) is created by the stimulated emission of photons. ~~with atoms~~ These photons are emitted due to being impacted by unstimulated photons, leading to a monochromatic coherent emission of radiation, as the photons are emitted in a controlled way. The laser is made up of layers of material, Aluminium Arsenic Oxide, which form the PN type area of the LED, there is then a confinement layer between the gap where emission takes place. The emission is given as ~~the~~ visible light and thus falls within this band of an EM spectrum.

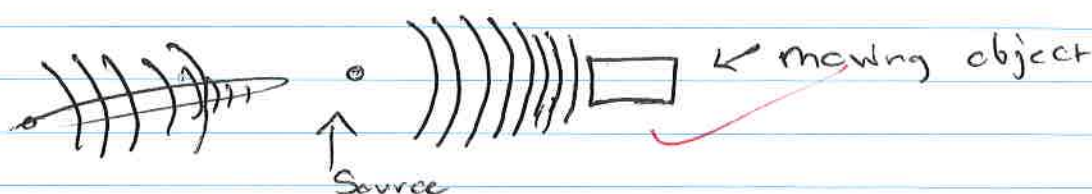
d) An isolator's purpose is to prevent an EM wave from damaging equipment connected to the waveguide if there is reflected power.

6.)

a.)



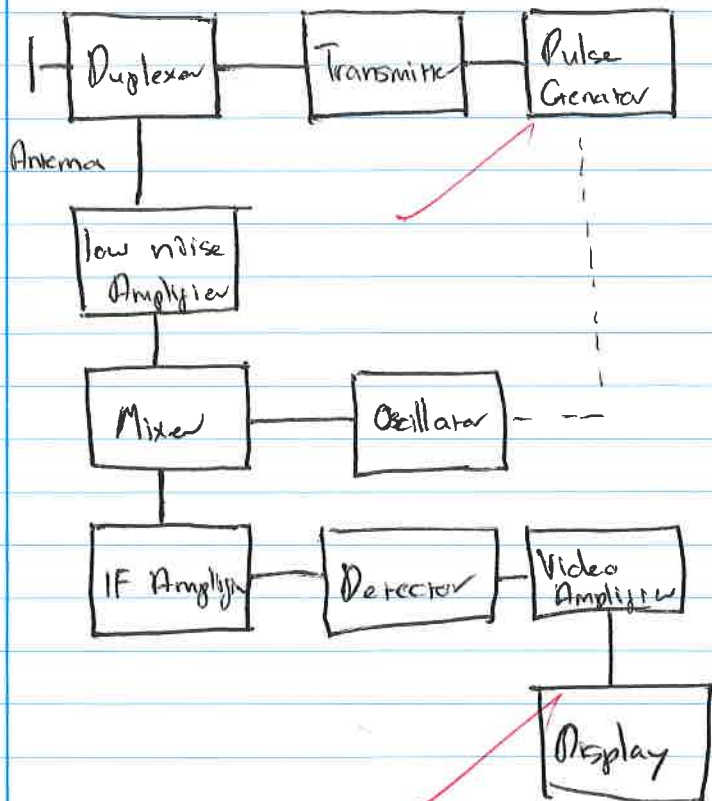
- b.) Doppler effect is the compression of echoed waves from a moving object with respect to the source, the compression being of the wavelength of the waves. Here the received waves will have a shorter wavelength and thus higher frequency to those ~~transer~~ transmitted. A real world example would be a car sounding its horn, as the car becomes closer, the pitch increases and as it moves away it decreases.



- c.) A pulse radar has a pulse generator, which is used to generate the pulse waveform. An ~~esett~~ transmitter is used to transmit the waveform and amplify the pulse for propagation via an antenna. First however, a duplexer is needed ^{between} ~~before~~ the antenna and transmitter to allow the radar to use the antenna to receive and

transmit. The received signal is amplified by a low noise amplifier to increase its amplitude to allow for signal processing. A mixer is used to generate an IF waveform using the received wave and a carrier generated by the oscillator, which generates sinusoidal waves. An IF amplifier then amplifies the IF wave and a detector is used to detect if the IF wave shows signs of an object being detected. The video amplifier is used to

amplify the output signal to the HMI interface, being the display.



Q6
 $4+2+4+3=13$

