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e)

12 Pages

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1	Student Number	2114762
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3	Module Code	ACDC5009
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5	Examination Venue	310
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7	Number of Answer Books handed in	2

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

80
100
PL 1

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1) a) An electromagnetic wave is a transverse wave which can propagate in a vacuum (no medium req.). It has electric & magnetic component.

2

b) Electromagnetic waves are transverse waves which can propagate in a vacuum (no medium required).

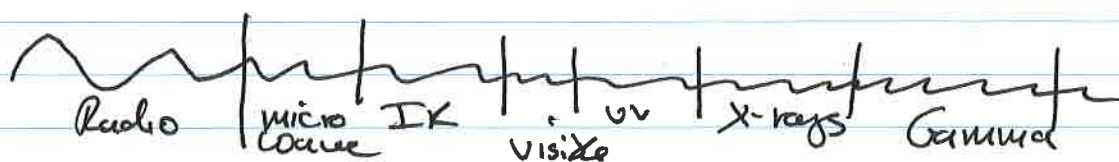
- Velocity $3 \times 10^8 \text{ m/s}$ in free space
- Can be polarised
- Have Electric & magnetic components
- Can be diffracted, ~~refracted~~ refracted, reflected & scattered when interacting with other mediums.
- High frequencies can be ionising
- Have many applications
- Humans are visible part of spectrum to see.

6

c) EM waves propagate perpendicular to their magnetic & electric fields/components. Are known as transverse waves.

2

d) EM spectrum is the total scope of wave lengths/frequencies of EM waves. Lowest frequencies are radio waves with highest being Gamma



2

Radio waves have the longest wavelength ($10,000 \text{ km} \rightarrow 1 \text{ mm}$) and lowest frequency $\leq 300 \text{ GHz}$.

The upper frequency band ($300 \text{ MHz} \rightarrow 300 \text{ GHz}$) are known as microwaves and are used for cooking, microwave ovens, telescopes & other things.

Radio waves at lower frequencies are used for RADAR, telescopes also & cooking including AM & FM (Amplitude modulated & frequency modulated) radio waves. AM waves are usually around 800 kHz as well as FM is higher frequency

3

1

16

at around 100 MHz.

- c) 2) TE Mode is a waveguide where the electric component does not move in the same direction as propagation.

$$2 + 1 + 2 + 2 + 3 + 1 + 1 = 12$$

- 2) a) Polarisation is the restricting a EM wave's ability to propagate either in a certain plane or



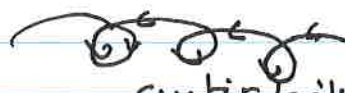
vertical polarised

types of polarisation

- Vertical
- Horizontal
- Right handed (clockwise)
- Left handed (anti-clockwise)



clockwise



anticlockwise



Polarisation allows H for
Polarisation allows directivity but also less
intensity less intensity and is commonly
used for sunglasses to protect our eyes
from intense sun-rays.

So An Antenna that is vertically polarised will not detect a signal that is horizontally polarised & vice versa. Right-hand / Left-hand

polarised antennas are normally use for comms with satellites

Polarisation works by blocking any wave that is not orientated in the polarised plane i.e horizontal wave cannot pass through a vertically polarised filter

b) $Q_1 = -2\mu C$ $-20\mu C$ $P(-6, 4, 6)$ $Q_2 = 50\mu C$ $R(5, 8, -2)$

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

$$\vec{PR} = (5 - (-6))\hat{a}_x + (8 - 4)\hat{a}_y + (-2 - 6)\hat{a}_z$$

$$\vec{PR} = 11\hat{a}_x + 4\hat{a}_y - 8\hat{a}_z$$

$$\hat{a}_{PR} = \frac{\vec{PR}}{|\vec{PR}|}$$

$$|\vec{PR}| = \sqrt{11^2 + 4^2 + 8^2} = 14.177$$

$$\hat{a}_{PR} = \frac{11\hat{a}_x + 4\hat{a}_y - 8\hat{a}_z}{14.177} = 0.776\hat{a}_x + 0.282\hat{a}_y - 0.564\hat{a}_z$$

$$\vec{F} = \frac{-20 \times 10^{-6} \times 50 \times 10^{-6}}{4\pi \times 8.854 \times 10^{-12} \times 14.177^2} [0.776\hat{a}_x + 0.282\hat{a}_y - 0.564\hat{a}_z]$$

$$\vec{F} = -0.0412 \times [0.776\hat{a}_x + 0.282\hat{a}_y - 0.564\hat{a}_z]$$

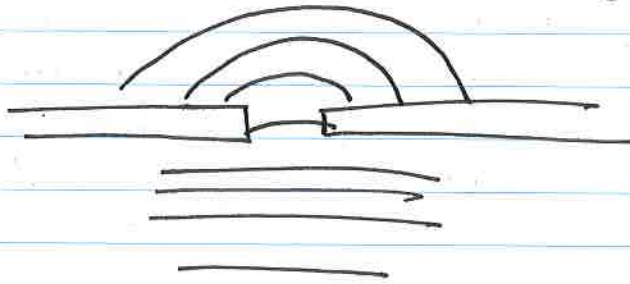
$$\vec{F}_{PR} = -0.0320\hat{a}_x - 0.0116\hat{a}_y + 0.0232\hat{a}_z$$

$$|\vec{F}_{PR}| = \sqrt{0.0320^2 + 0.0116^2 + 0.0232^2}$$

$$= 0.04119$$

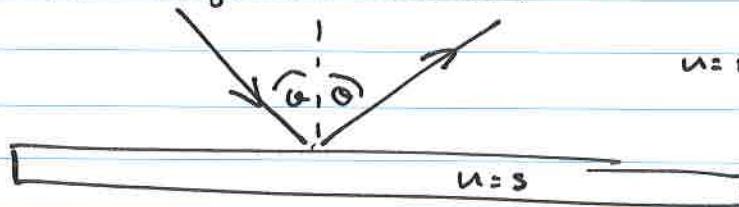
Q2
2+2+2+2+2+2 = 12

3)a)i) Diffraction $\rightarrow$ Spreading out of a wave when travelling through a gap less $<$ wavelength



Higher frequencies diffract more

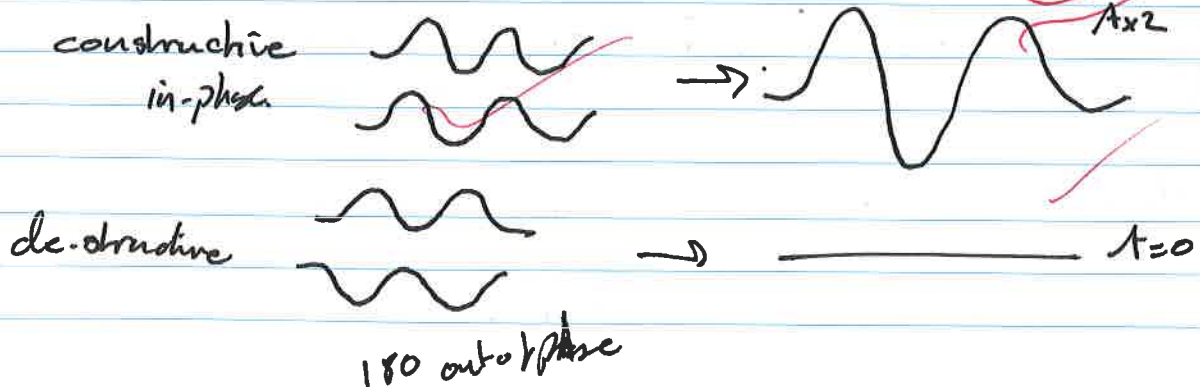
ii) total internal reflection is ~~the~~ when a wave sources of a medium back into the original medium



iii) Scattering is when a wave is dispersed when interacting with a medium

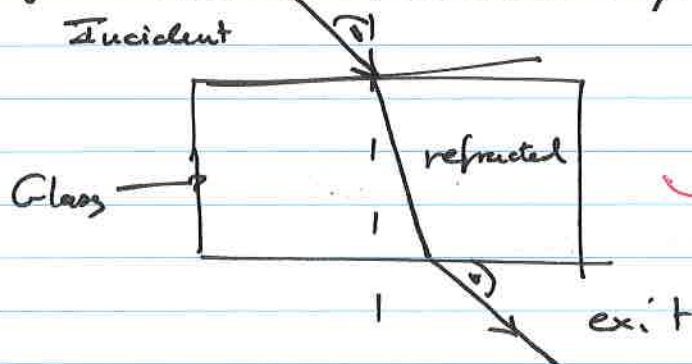


iv) Interference is when waves interact with one another either constructively or destructively



If both waves are not totally in or out of phase the interacted wave will be sum or difference.

- v) Refraction is when waves bend when going through another medium i.e. from air to glass



High frequencies refract more.

- b) A waveguide is a component which allows waves to flow in ^aother direction i.e. they guide waves. They can be rectangular or circular



Depending on the wave depends on the wire i.e. radio waves will use copper, light uses optical fibres and sound uses hollow tubes.

Types TEM, TM, TE & hybrid. E - Electric
M - Magnetic

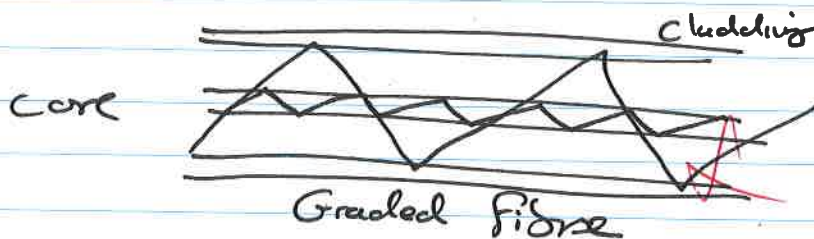
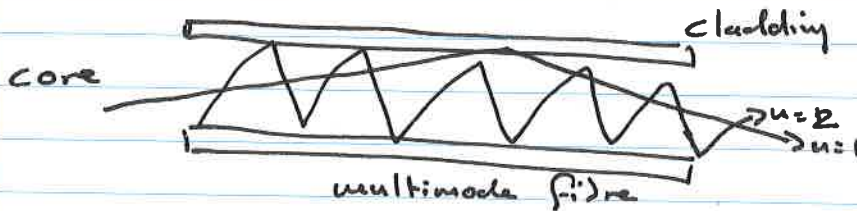
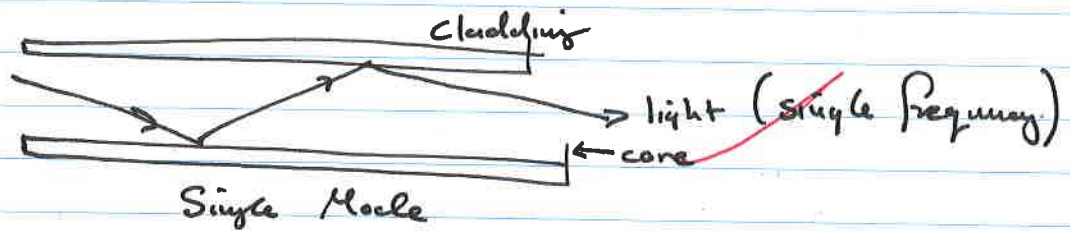
→ TEM - M or E does not travel in same direction as propagation

→ TE - E does not travel in same direction as propagation

→ TM - M does travel in same direction as propagation

→ Hybrid - Allows both to travel in same

direction as propagation.



Optical Fibres are glass waveguides surrounded by a cladding which reflects light back into the core and stops any signal escaping.

Single mode fibre is a fibre of one grade which transmits a single frequency (ie red light). It is simplest.

Multimode is the still a single grade of fibre but transmit multiple frequencies (ie white light). Not commonly used as it causes multipath dispersion as high frequency waves reflect more creating a longer path and so reaches destination after the lower frequency wave.

Graded optical fibres solve this by having multiple grades of fibres in the core which ensure different frequencies are reflected to

same amount and therefore follow the same path. This prevents multipath dispersion as all signals arrive at the destination at the same time.

$$4) a) P_v = 102^{3.6} x \sin \pi y \quad (-1 \leq x \leq 2) \quad (0 \leq y \leq 1) \quad (3 \leq z \leq 3.6)$$

$$\iiint_{-1}^{2} \int_0^1 \int_3^{3.6} 102^{3.6} x \sin \pi y \, dx \, dy \, dz$$

$$10 \iiint_{-1}^{2} \int_0^1 \int_3^{3.6} 2^{3.6} x \sin \pi y \, dx \, dy \, dz$$

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

$$10 \times \left[\frac{3.6^3}{3} - \frac{3^3}{3} \right] \times \left[\frac{4^2}{2} - \left(\frac{(-1)^2}{2} \right) \right] \times \left[\frac{-\cos \pi \times 1}{\pi} - \left(\frac{-\cos \pi \times 0}{\pi} \right) \right]$$

$$10 \times [6.552] \times [1.5] \times [0.6366]$$

$$P_v = \underline{62.57 \text{ C}}$$

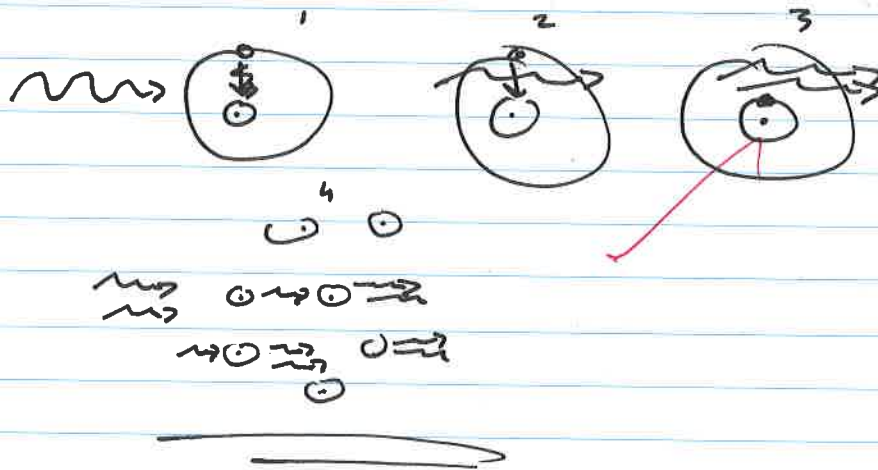
$$b) \quad n_1 = 1.80 \quad n_2 = 1.47$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad / \quad \theta_a = \sin^{-1} \frac{n_2}{n_1}$$

$$\sin^{-1} \left(\frac{1.47}{1.80} \right)$$

$$\text{Critical / Acceptance angle} = \underline{78.52^\circ}$$

- c) Lasers use stimulated emission to produce waves in-phase, of same magnitude & direction. Stimulated emission by passing a photon past an excited atom where the photon's energy matches that of the difference between the excited atoms excited and ground state. When this happens the excited electron drops to the ground state which then produces a matching photon. This process then continues creating an avalanche-like effect.



- d) Isolator waveguide isolates the signal as much as possible stops reflection of it or continued transmission.

$$4 + 2 + 2 + 2 = 10$$

5) a) $t = \mu d \ln\left(\frac{b}{a}\right)$ $\mu = \mu_0 / \mu_r$ $\mu_r = 1$
 $L = \frac{L}{d} = \frac{\mu}{2\pi} \ln\left(\frac{b}{a}\right)$ $\mu = 4\pi \times 10^{-7}$

$$\frac{L}{d} = \frac{4\pi \times 10^{-7} \times \ln\left(\frac{3 \times 10^{-3}}{1 \times 10^{-3}}\right)}{2\pi} = \underline{\underline{0.2197 \mu\text{H/m}}}$$

b) $Z_o = 550 \angle 60^\circ \Omega$ $Z_{sc} = 500 \angle -14^\circ \Omega$

$$Z_o = \sqrt{Z_{oc} \times Z_{sc}}$$

$$\tanh \gamma = \sqrt{\frac{V_{sc}}{V_{oc}}}$$

$$Z_o = \sqrt{550 \times 500} \angle 60 - 14$$

$$\gamma = \tanh^{-1} \sqrt{\frac{V_{sc}}{V_{oc}}}$$

$$Z_o = \sqrt{275000} \angle 46$$

$$\gamma = \alpha + j\beta$$

$$Z_o = \underline{\underline{524.40 \angle 23^\circ \Omega}}$$

$$\tanh \gamma = \frac{e^{2\gamma} - 1}{e^{2\gamma} + 1}$$

$$\gamma = \tanh^{-1} \sqrt{\frac{500 \angle -14}{550 \angle 60}}$$

$$\gamma = \tanh^{-1} 0.953 \angle -37^\circ$$

$$\tanh \gamma = 0.953 \angle -37^\circ$$

$$\frac{e^{2\gamma} - 1}{e^{2\gamma} + 1} = 0.953 \angle -37^\circ$$

$$\gamma = \frac{e^{2\gamma} - 1}{e^{2\gamma} + 1} = 0.761 - j0.574j$$

$$e^{2\gamma} - 1 = 0.761 - j0.574(e^{2\gamma} + 1)$$

$$e^{2\gamma} - 1 = 0.761 - j0.574 + 0.761e^{2\gamma} + j0.574e^{2\gamma}$$

$$e^{2\gamma}$$

b)

$$Z_{oc} = 550 \angle -60^\circ$$

$$Z_{sc} = 500 \angle -14^\circ$$

$$Z_o = \sqrt{Z_{oc} \times Z_{sc}}$$

$$Z_o = \sqrt{550 \times 500 \angle -60^\circ - 14^\circ}$$

$$\sqrt{275,000 \angle -74^\circ}$$

$$Z_o = \underline{\underline{524.40 \angle -37^\circ}}$$

$$\gamma \tanh^{-1} \sqrt{\frac{500 \angle -14^\circ}{550 \angle -60^\circ}}$$

$$\gamma = \tanh^{-1}(0.953 \angle 23^\circ)$$

$$\tanh \gamma = 0.953 \angle 23^\circ$$

$$\frac{e^{2\gamma} - 1}{e^{2\gamma} + 1} = 0.953 \angle 23^\circ$$

$$\frac{e^{2\gamma} - 1}{e^{2\gamma} + 1} = 0.877 + j0.372$$

$$e^{2\gamma} - 1 = 0.877 + j0.372 (e^{2\gamma} + 1)$$

$$e^{2\gamma} - 1 = 0.877 + j0.372 + 0.877e^{2\gamma} + j0.372e^{2\gamma}$$

$$e^{2\gamma} - 0.877e^{2\gamma} - j0.372e^{2\gamma} = 0.877 + 1 + \underline{\underline{j0.372e^{2\gamma}}}$$

$$e^{2\gamma} [1 - 0.877 - j0.372] = 1.877 + j0.372$$

$$e^{2\gamma} [0.123 - j0.372] = 1.877 + j0.372$$

$$\tanh \gamma = \sqrt{\frac{Z_{sc}}{Z_{oc}}}$$

$$\gamma = \tanh^{-1} \sqrt{\frac{Z_{sc}}{Z_{oc}}}$$

$$\gamma = \alpha + j\beta$$

$$\tanh \gamma = \frac{e^{2\gamma} - 1}{e^{2\gamma} + 1}$$

$$e^{2r} = \frac{1.877 + j0.372}{0.123 - j0.372}$$

$$r = \sqrt{x^2 + y^2}$$

$$\phi = \tan^{-1} \left(\frac{y}{x} \right)$$

$$r_1 = \sqrt{1.877^2 + 0.372^2} = 1.914$$

$$\phi_1 = \tan^{-1} \left(\frac{0.372}{1.877} \right) = 11.21$$

$$r_2 = \sqrt{0.123^2 + 0.372^2} = 0.392$$

$$\phi_2 = \tan^{-1} \left(\frac{0.372}{0.123} \right) = 71.70$$

$$e^{2r} = \frac{1.914 \angle 11.21^\circ}{0.392 \angle 71.70^\circ}$$

$$e^{2r} = 4.883 \angle -60.49^\circ$$

$$2r = \ln (4.883 \angle -60.49^\circ)$$

$$r = \ln 4.883 \angle -60.49^\circ$$

$$\frac{\ln(4.883) - j60.49}{2}$$

$$r = 0.793 - j30.25$$

$r =$

$$\alpha = 0.793$$

$$\beta = -30.25^\circ$$

$$2+2+3+3+2+3+14=17$$

6) a) TEM 12 W/m^2 $\epsilon_r = 3$ $\mu_r = 1$

$$\vec{E} \& \vec{H}$$

$$= \vec{E}_{\max}$$

$$P_{\text{power}} = \frac{\vec{E}_{\max}^2}{2\eta}$$

$$\frac{\vec{E}_{\max}}{H_{\max}} = \eta_0$$

$$\eta = \sqrt{\frac{\mu_0 \mu_r}{\epsilon_0 \epsilon_r}}$$

$$\mu_0 = 4\pi \times 10^{-7}$$

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

$$\eta = \sqrt{\frac{4\pi \times 10^{-7} \times 1}{8.854 \times 10^{-12} \times 3}} = \underline{\underline{217.51}}$$

$$P_{\text{power}} = \frac{\vec{E}_{\max}^2}{2\eta}$$

$$P \times 2\eta = \vec{E}_{\max}^2$$

$$2\eta \sqrt{P} = \vec{E}$$

$$\sqrt{P \times 2\eta} = \vec{E}$$

$$\vec{E} = \sqrt{12 \times 435.02} = \underline{\underline{72.25}}$$

$$\frac{\vec{E}_{\max}}{H_{\max}} = \eta_0$$

$$H_{\max} = \frac{\vec{E}_{\max}}{\eta_0} = \frac{72.25}{376.73}$$

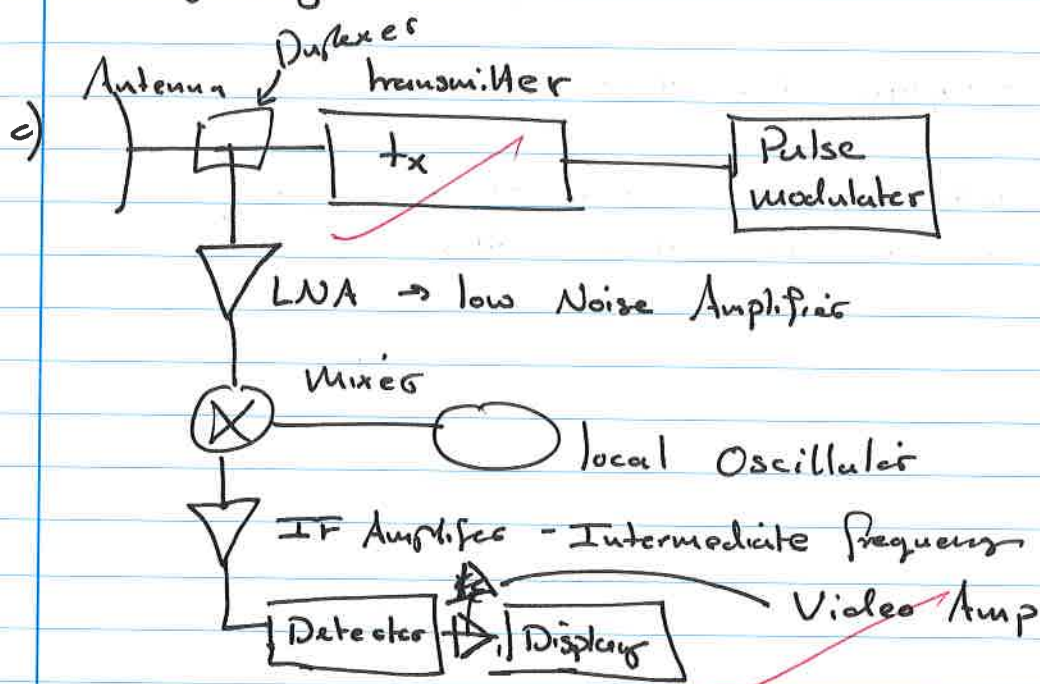
$$= \underline{\underline{0.1918}}$$

$$\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$$

$$= 376.73$$

6)b) The doppler effect is the change of frequency of a wave when transmitted / reflected of a moving object. An example of this is a moving car. When it is moving towards you the waves are squashed slightly increasing their frequency. When moving away the waves are stretched and frequency is decreased.

This application is used in continuous wave radar to detect and analyse the motion of moving objects.



Antenna → Propagates transmitted signal and receives propagated signals from elsewhere.

Duplexer → Acts as a switch (transmit / receive) to stop the need for 2 antennas

Transmitter → transmits the signal

Pulse Mod → Creates the pulse pulse modulation

LNA → Amplifies the weak received signal.

Mixer $\rightarrow$ mixes received signal with local oscillator to produce sum & difference.

Local Oscillator $\rightarrow$ Creates a stable reflective sinusoidal signal to be used in the mixer.

IF Amplifier $\rightarrow$ Amplifies the intermediate frequency produced by the mixer.

Detector $\rightarrow$ Detects if signal is present

Video Amp $\rightarrow$ Amplifies the video signal.

Display $\rightarrow$ Displays the signal on a screen for the user to interact with.

Q6
 $2+4+3+6=15$

