



Complete, fold and seal
(see note 2 below)

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Examination Answer Books

12 Pages

Instructions to Candidates

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.

1	Student Number	1810364
2	Title of Examination Paper	Electromagnetic Radiation
3	Module Code	ACDA5009
4	Date and Time of Examination	03/05/22 10:00
5	Examination Venue	IQ Building Room 002
6	Seat Number	
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
1	19
2	10
3	16
4	22
5	26
6	19
Total	

1 to 1

Question No.

Examiner Only

- ① a) Radio ✓
 Microwave ✓
 Ultraviolet ✓
 Visible Light ✓
 Infrared ✓
 X-Ray ✓
 Gamma ✓

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- b) Radio induces current in a conductor (i.e. Antenna) ✓
 Microwave induces current in a conductor and induces heat in dielectrics ✓
 Ultraviolet is not visible to the human eye and is biologically harmful (sunburn) ✓
 Visible light is visible to the human eye. ✓
 Infrared does not induce current in a conductor but does induce heat in conductors and non conductors. ✓
 X-Ray is ionising radiation produced by electrons. ✓
 Gamma is ionising radiation produced by nuclei. ✓

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- c) Refraction is the change in direction of light as it passes from one medium to another. ✓
 Waves

- d) Diffraction is the bending of light round the corner of an obstacle or through an aperture. ✓
 Waves

- e) Dispersion is the separation of light in a wavelength. ✓

- f) Specular reflection is the change in direction of light as it strikes the surface of another medium. ✓

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- g) Diffuse reflection is the scattering of light in all directions when it strikes a rough or matt surface.

- h) Transmission is the passing of light through a medium with no absorption. ✓

- i) Absorption is the transfer of energy to the medium as light passes through it. ✓

Waves, not just light.

②

Q1 - 19

Arholwr yn unig

Rhif y Cwestiwn

② a) Speed of light is 3×10^8
 Frequency is 433×10^6

$$\frac{3 \times 10^8}{433 \times 10^6} = \frac{3 \times 10^2}{433} = \frac{300}{433} = 0.69 \text{ m}$$

$\therefore$ because it is quarter length $\frac{0.69}{4} = 0.17 \text{ m}$

0.17m is the optimum length.

- b)
- Line of sight is to be maintained / no obstructions
 - Orientation of the antenna as this affects polarisation of the radio waves. Best one would be vertical.
 - Ground plane, so the metal ^{plate} bases of the antenna when transmitting, the radio waves reflect off the plate into the atmosphere.

c) Using inverse square law $I_1 d_1^2 = I_2 d_2^2$

$I_1 = 10 \text{ mW}$
 $d_1 = 90 \text{ m}$
 $d_2 = 270 \text{ m}$
 $I = ?$

$$\therefore \frac{I_1 d_1^2}{d_1^2} = I_2$$

$$\therefore \frac{10 \times 270^2}{90^2} = 90$$

Power output would need to be 90mW.

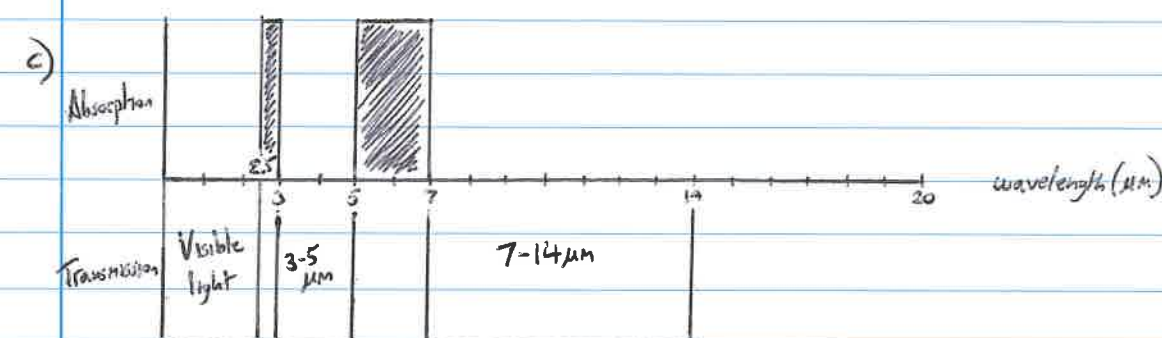
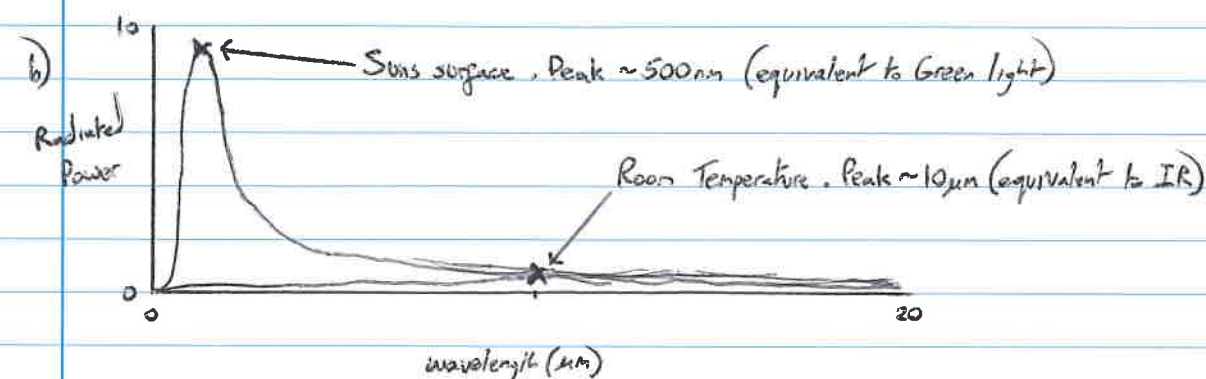
- d) You could change the design of the antenna to directional (Yagi).
 You could use radar tracking.
 You could install multiple ground stations along the flight path.

e) 6 degrees of freedom each requiring 8-bits so $6 \times 8 = 48$
 data rate is 40kb/s so 40,000 bits

$$\frac{48}{40,000} = 1.2 \times 10^{-3} \quad \therefore \text{The shortest time interval is } 1.2 \text{ ms} \text{ between transmissions.}$$

Q2-10

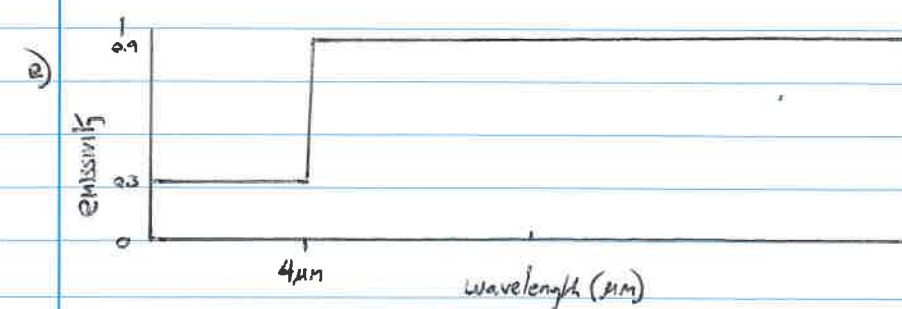
- ③ a) A blackbody radiator is an object that absorbs all electromagnetic radiation at all frequencies and at all angles of incidence.



Much of the atmosphere is opaque to IR frequencies, this is because the IR frequencies resonate with gasses and vapours in the atmosphere (nitrogen, hydrogen and water molecules).

- d) Emissivity is the ratio of energy radiated from a materials surface to that of energy radiated from a perfect emitter, known as a blackbody, at the same temperature and wavelength, and under the same viewing conditions. It is scaled between 0 and 1. Emissivity is affected by whether the object is in freefield or surrounded by stuff?

Polished silver is ~ 0 (0.02) and black paint is ~ 1 (0.97)



- ③ f) Military use dark olive green paint, it is designed to absorb all frequencies/wavelengths for security purposes.

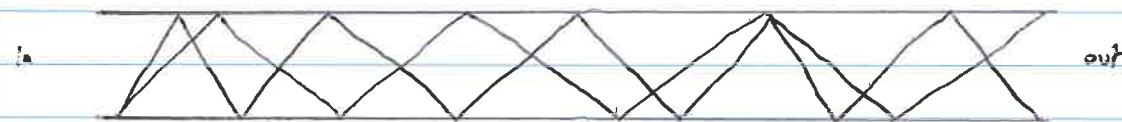
White paint contains titanium oxide which radiates/emits energy at a higher wavelength than it is receiving. It reflects the heat of the sun, whilst maintaining self temperature.

(-1)

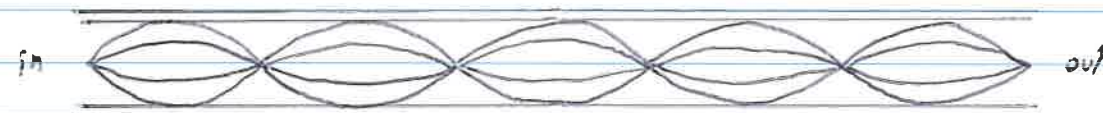
Q3-16

- ④ a) Possible advantages are -
- cost effective ✓
 - more reliable (doesn't corrode) ✓
 - more secure ✓
 - higher bandwidth ✓
 - greater range ✓
 - duplex operation (sends information both ways) ✓
 - less susceptible to interference ✓
 - lightweight/smaller diameter ✓

- b) Step Index multimode - when light passes through there are multiple refractions which generates paths of ~~not~~ variable lengths. It has limited range and data rate (1km, 1Mb). It is robust and cheap.



Graded Index Multimode - consists of two glass types with different refractive index. The light is refracted and focussed in the centre of the cable. Higher frequencies refract more and as a result take the shorter paths. It has average range and data rate (10km, 100Mb). It is average in robustness and cost.



Mono-mode - the light travels down the center of the cable with little to no dispersion. It has a greater range and bandwidth (100km, 1Gb). It is expensive and not robust.



- c) cost ✓
 distance (range from target before initiated) ✓
 robustness (survivability on launch) ✓
 data rate (comms) ✓
- Speargish typically required to travel up to 10km at 80knots. Doesn't require high resolution or data rate. The wire would need to be robust and water-resistant.

(4) c)
continued)

- ① Graded index multimode as meet all the requirements.
- ② Step index multimode could be used but would have to launch close to the target.
- ③ Mono-mode would be unlikely to survive launch due to lack of robustness.

Q4 - 22

5

(5) a)

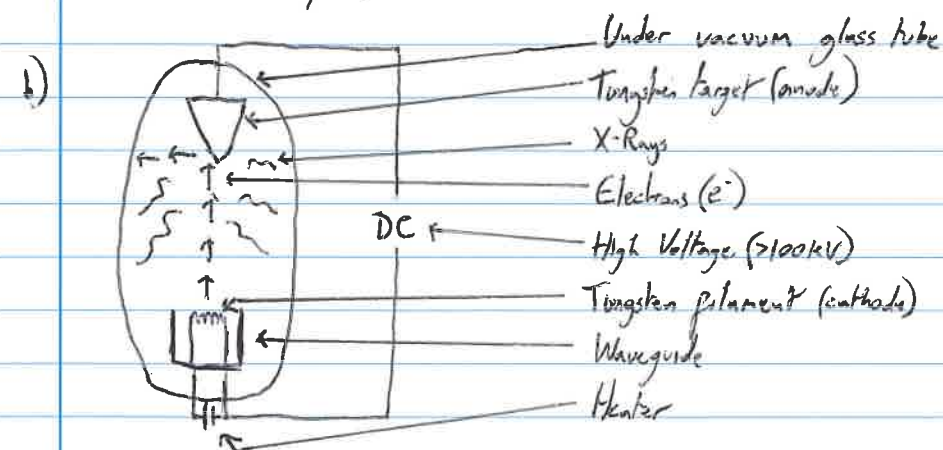
Non destructive testing or exploitation

X-ray plashes to measure quick events i.e. shaped charge
Security purposes / EOD purposes

Crystallography to determine material properties

Inspection of internal assemblies for quality control.

Nuclear weapons.



- c) Electrons are fired at the anode and knock out electrons from the innermost shell. Electrons from the outer shell move down to fill the gap. This movement produces the X-ray.

- d) The Compton effect is where a photon ^{scattered on interaction} interacts with a charged particle, usually an electron, this results in a decrease of energy in the photon.

- e) Factors which ~~affect~~ determine absorption of X-rays are
- thickness (t)
 - density (ρ)
 - atomic mass (A)
 - atomic number (Z)
 - X-ray energy (E)

- f) $\mu \propto \frac{\rho Z^4}{AE^3}$ These are not linear.
 μ is the absorption coefficient.
thickness is relative.

- g) Gamma radiation produced as a result of nuclear explosion in the atmosphere, such that the Compton effect occurs, generates electric fields in the atmosphere. These time-varying fields induce currents in conductors.

Q5 - 26

- (6) a) Four inferences drawn from Bio-Savart law are - directly proportional to current
 state that the magnitude of magnetic induction is $\left\{ \begin{array}{l} - \text{directly proportional to angle} \\ - \text{directly proportional to length of conductor} \\ - \text{inversely proportional to square of distance} \end{array} \right. \quad \textcircled{1}$

2
2
2
3

b) force = length $\times$ power $\times$ magnetic field strength

$$\therefore 1\text{m} \times 1\text{A} \times 1\text{T} = 1 \text{ Newton}$$

5

c/d) $L = \frac{\mu N^2 A}{l}$ $L = \text{inductance} = 40\mu\text{H} (40 \times 10^{-6})$
 $\mu = \text{permeability} = 4\pi \times 10^{-7}$
 $A = \text{area} = \pi r^2 = (\pi (0.01)^2)$
 $l = \text{length} = 10\text{cm} = 0.1\text{m}$

need to find N $\therefore N = \sqrt{\frac{Ll}{\mu A}}$

$$\therefore \sqrt{\frac{(40 \times 10^{-6})(0.1)}{(4\pi \times 10^{-7})(\pi (0.01)^2)}}$$

$$= 100.66 \text{ turns in the coil} \quad \therefore 101 \text{ turns in the coil.}$$

5

~~Q5 - 26~~

Q6 - 19