



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Examination Answer Books

12 Pages

Complete, fold and seal
(see note 2 below)

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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	1810444
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	1Q 002
6	Seat Number	
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	21
2	10
3	16
4	22
5	26
6	16
Total	

(Gweler yr ochr arall am y fersiwn Cymraeg)

1 a) Radio, microwave, infrared, visible, ultra-violet, x-ray & gamma

7

b) radio: photon energy less than $1.24 \mu\text{eV}$
can induce currents in conductive materials

microwave: photon energies between $1.24 \mu\text{eV}$ and 1.24meV
can induce currents in conductive materials
can induce heating in dielectric materials

infrared: photon energies between 1.2meV and 1.3eV
can induce heating in conductive & insulative materials
cannot induce currents

visible: photon energies of $1.3 - 7 \text{eV}$
can be perceived by the human eye

7

ultra-violet: photon energies between 7eV & 124eV
cannot be perceived by the human eye
is biologically damaging

x-ray: photon energies between 124eV and 1.24keV
ionising radiation produced by electrons

gamma: photon energies above 1.24keV
ionising radiation produced by molecules

- 1c refraction is the bending of a wave's path of transmission as it passes into a medium with a different refractive index



- 1d diffraction is the bending of a wave front as it passes through an aperture or the corner of an object



- 1e dispersion is the separation of an electromagnetic wave (ie white light) into its separate frequencies



- 1f. specular reflection is the mirror-like reflection of light where an incident wave is bounced off a surface coherently & the angle of incidence equals the angle of reflection



- 1g diffuse reflection is where the incident wave is bounced off of a surface at multiple angles (such as for a rough surface)



- 1h transmission is the passage of an electromagnetic wave through a medium

- 1i) absorption is where an electromagnetic wave loses energy to a medium as it moves through

Q1 = 21

2a)

$$c = f \lambda \quad \therefore \lambda = c/f$$

$c = \text{speed of light } 3.0 \times 10^8 \text{ ms}^{-1}$
 $f = \text{frequency of wave } 433 \times 10^6 \text{ Hz}$

$$\lambda = \frac{3.0 \times 10^8}{433 \times 10^6} = 0.6928 \text{ m}$$

optimal length of quarter-wave antenna =
 quarter of wave length

$$\frac{0.6928}{4} = \underline{\underline{0.17 \text{ m}}}$$

2b)

orientation of missile to ground station
 line of sight
 ionising exhaust fumes
 pitch/yaw of rocket in flight
 spin of rocket in flight

2c) signal power follows law of inverse squares

$10 \text{ mW} = 90 \text{ m}$ 270 m is 3 times as far
 so power = $(\frac{1}{3})^2 \times 10 = \underline{\underline{1.1 \text{ mW}}}$

2d) high gain antenna such as a yagi that is directional



2e)

6 degrees of freedom each requiring 8 bits
 $\Rightarrow 6 \times 8$ bits per transmission
 48 bits

speed is 40 kbits/s

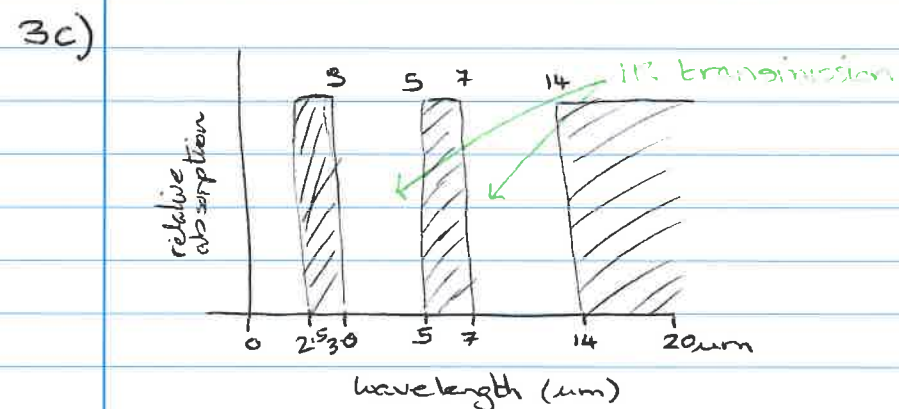
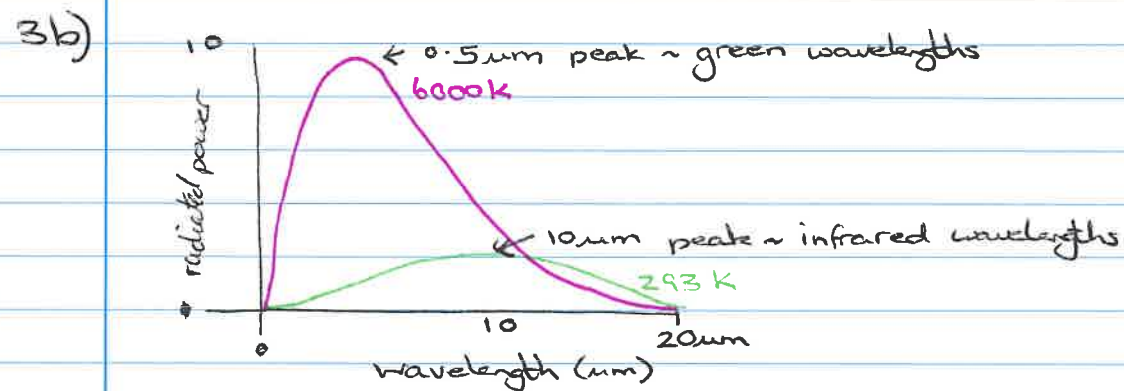
$$\text{time for transmission} = \frac{48 \text{ bits}}{40 \text{ kbits/s}}$$

$$= 1.2 \times 10^{-3} \text{ s}$$

$$= \underline{\underline{1.2 \text{ ms}}} \text{ required between transmissions}$$

$$Q2 = 10$$

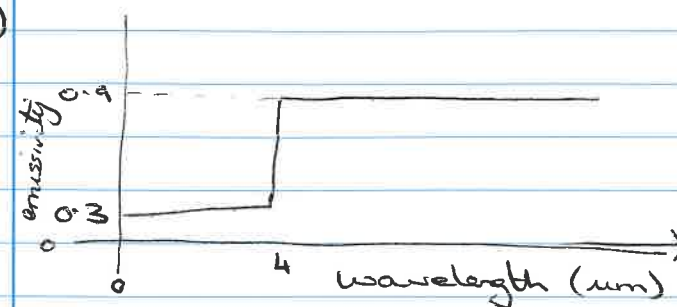
3a) A black body radiator is an object which absorbs all incident electromagnetic radiation at all incident angles & frequencies



infrared radiation is absorbed by the molecules in the air such as H_2O .

3d) emissivity is the ratio of emitted energy from an object to that emitted by a black body at the same temperature for the same wavelength
polished silver has an emissivity of approximately 0.2
black paint has an emissivity of approximately 0.98

3e)



3

3f) Shipping containers painted white will be cooler because they reflect incoming solar radiation well and emit infrared radiation well at long wavelengths consistent with the temperatures of $30-50^{\circ}C$.
Therefore they take in (absorb) less energy than olive green containers and emit more making them overall cooler temperatures

Q3 = 16

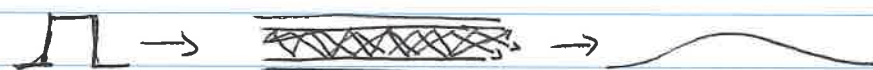
4

3

4a)

smaller mass
 smaller diameter core
 duplex communication
 higher bandwidth
 less susceptible to noise
 less susceptible to 'snooping'
 cheaper cost
 more reliable
 more rugged
 lower pulse dispersion
 can communicate over larger distances

b) step index multi-mode: light of multiple frequencies is passed down a fibre using internal reflection which causes the light to disperse



graded index multi-mode: light of multiple frequencies is passed down a fibre whose inner core has graded refractive index which appears to bend light more or less (dependent on frequency) to keep them semi-coherent



monomode optical fibre: light of a single frequency is passed down a narrow core of fibre



step index is the cheapest & most rugged but has low bandwidth (10MHz) & short transmission lengths (1km)

multimode is expensive & more fragile with a high bandwidth (1GHz) & long transmission lengths (100km)

graded is middling cost & ~~rugged~~ robustness with a middling bandwidth (100MHz) & middling transmission lengths (10km)

4c)
 ✓ robustness - highest priority
 ✓ bandwidth
 ✓ transmission length
 ✓ cost - lowest priority

I would recommend step index multimode (if it has sufficient bandwidth and transmission length as it is the most robust).

If a higher bandwidth or transmission length is required I would then recommend multimode graded index.

given the cost of a torpedo the difference in costs for the ~~two~~^{three} types of fibre is very small & therefore low priority

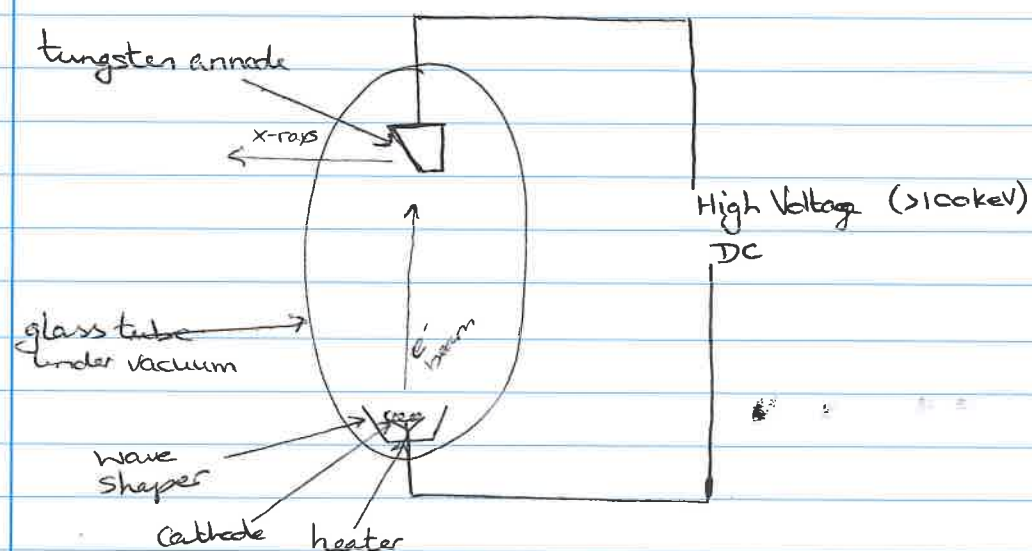
robustness is highest priority as it is very important the cable survives up to the point it is needed & survives unspooling quickly & survives deployment in pressurised environment. ~~However~~

bit rate requirements should be low enough for step mode

Q4 : 22

- 5a) for detection - such as x-ray scanners
 for inspection - such as EOD
 for imaging - such as flash x-ray
 for crystallography

5b)



- 5c) electrons are fired from the cathode and directed by the wave shaper onto the anode (tungsten target)

The incoming electron ~~knocks~~ impacts an electron in the ^{innermost} ~~outer~~ ring of a tungsten atom giving it sufficient energy to escape the molecule.

An electron from the outer rings of the same molecule then moves inwards emitting the energy difference as an x-ray photon

4

- 5d) The Compton effect is when a photon loses energy to charged particles (typically electrons) as it moves through the medium.

2

- 5e) Thickness of medium
 density of medium ρ
 atomic mass of medium A
 atomic number of medium Z
 energy of incident x-ray photon E

5

5f)
$$\mu = \frac{\rho Z^4}{AE^3}$$

4

- 5g) The nuclear explosion creates ~~gamma~~ high energy photons. photons lose energy to electrons which are moving. electrons generate a charged electric field which is moving. electric field induces currents in nearby conductive materials

3

Q5 = 26

- 6a) directly proportional to current in conductor
 directly proportional to length of conductor
 directly proportional to angle between magnetic & conductor
 indirectly proportional to separation of magnetic induction & conductor

(-4)

- 6b) force = 1 N due to definition of 1 Tesla being

6d) $L = \frac{\mu N^2 A}{l}$ $Ll = \mu N^2 A$ $\frac{Ll}{\mu A} = N^2$

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

$$L = 40 \mu\text{H}$$

$$l = 0.1 \text{ m}$$

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

$$A = \pi (0.01)^2$$

$$N = \sqrt{\frac{(40 \times 10^{-6})(0.1)}{(4\pi \times 10^{-7})(\pi (0.01)^2)}} \Rightarrow \sqrt{\frac{4.0 \times 10^{-6}}{3.9478 \times 10^{-10}}} \Rightarrow \sqrt{10132}$$

$$= 100.66$$

$\therefore$ 101 turns will be required to ensure the value of the inductor is at least 40 μH .

$$Q6 = 16$$