AQA

SPECIMEN MATERIAL

A-level
PHYSICS
(7408/3BB)

Paper 3 – Section B (Medical Physics)

Specimen 2014 Morning Time allowed: 2 hours

Materials
For this paper you must have:
- a pencil
- a ruler
- a calculator
- a data and formulae booklet
- a question paper / answer book for Section A.

Instructions
- Answer **all** questions.
- Show all your working.
- The total time for both sections of this paper is 2 hours.

Information
- The maximum mark for this section is 35.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number Candidate number

Surname

Forename(s)

Candidate signature

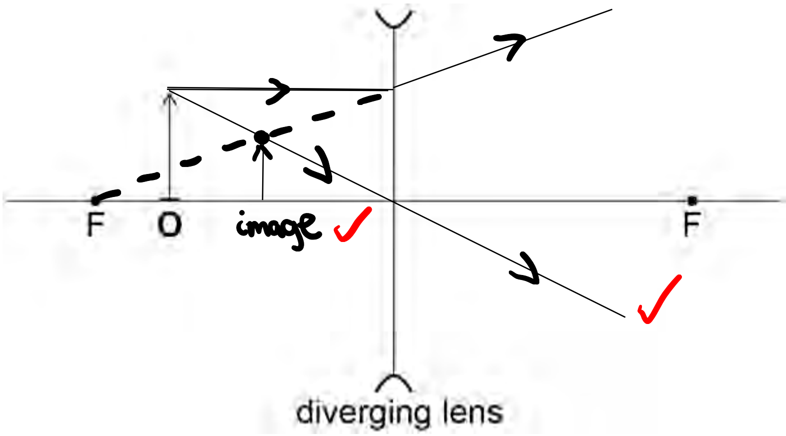
State what is meant by the principal focus and the power of a converging lens.

[2 marks]

- The principal focus is the point on the principal axis through which rays refracted by the lens travel, if they were parallel to the principal axis initially. ✓
- Power = $\frac{1}{\text{focal length}}$, measured in ✓

Complete the ray diagram below to show the formation of an image of a real object O by a diverging lens. Label the image clearly.

[2 marks]



State the defect of vision that would be corrected using a diverging lens.

[1 mark]

Short-sightedness (myopia)

A diverging lens of focal length −0.33 m is used to view a real object placed 0.25 m from the lens.

Calculate the distance from the lens to the image.

[2 marks]

$$\frac{1}{\text{focal length}} = \frac{1}{\text{object distance}} + \frac{1}{\text{image distance}}$$

$$\frac{1}{-0.33} = \frac{1}{0.25} + \frac{1}{d} \checkmark \Rightarrow d = \left(\frac{-1}{0.33} - \frac{1}{0.25}\right)^{-1}$$

$$= -0.1422\,\text{m}$$

distance from lens to image = −0.14 ✓ m

Two point sources of light are viewed by a normal eye and their images are formed at the fovea.

State, in terms of the active receptors, the conditions necessary for two separate images to be seen.

cones

[2 marks]

- Cones are active and stimulated by the light ✓
- Cones which are stimulated need to be separated by at least one unstimulated cone ✓

Sound waves are incident on a human ear.

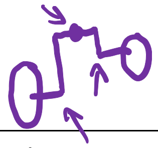
Describe how the frequency and amplitude of the vibrations change as the wave is transmitted through the ear to the fluid in the inner ear.

[2 marks]

• No change in frequency ✓
• Amplitude is reduced ✓

Explain how the components of the ear act to amplify the pressure changes due to the sound wave.

[3 marks]



$M = Fd$

• Ossicles produce a lever system, which increases the force ✓

$P = \frac{F}{A}$ $A\downarrow$, $P\uparrow$

• Ear drum has a much larger area than oval window ✓
• Pressure $= \frac{F}{A}$, so pressure increases ✓

A sound intensity meter, set to the dB scale, is placed near to a source of sound. The intensity level reading on the sound meter is 82 dB.

Calculate in, $W\ m^{-2}$, the intensity of the sound at the meter.

[3 marks]

$$I(dB) = 10\log_{10}\left(\frac{I}{I_0}\right)$$

$$82 = 10\log_{10}\left(\frac{I}{1.0\times10^{-12}}\right) ✓$$

$$\frac{82}{10} = 8.2 = \log_{10}\left(\frac{I}{1.0\times10^{-12}}\right) \Rightarrow 10^{8.2} = \frac{I}{1.0\times10^{-12}} \Rightarrow I = 1.0\times10^{-12}\times10^{8.2} ✓$$

$$= 1.58489\times10^{-4}$$

intensity = 1.6×10^{-4} ✓ $W\ m^{-2}$

The sound intensity meter is 2.0 m from the source which is emitting sound equally in all directions.

Calculate the power emitted by the source.

Intensity = $\frac{\text{Power}}{\text{Area}}$

[2 marks]

$A = 4\pi r^2 = 4\pi(2.0)^2$

$P = IA = 1.6\times10^{-4} \times 4\pi(2.0)^2$ ✓ $= 8.0425\times10^{-3}$ W

$\simeq 8.0\times10^{-3}$ W

power = 8.0×10^{-3} ✓ W

Positron Emission Tomography (PET) and ultrasound scans are both used in medical diagnosis. Compare the quality of the information obtained from these scans in terms of:

- patient safety and convenience
- information available to the doctor from the images.

[6 marks]

Safety and Convenience

PET	Ultrasound
• Moderate to high exposure to ionising radiation	• No exposure to ionising radiation
• 2-4 hours to carry out	• 10-15 minutes to carry out
• Injection required	• No injection required
• Must lie still in a confined space	• Able to move but a cold gel is required

Information

PET	Ultrasound
• Able to determine chemical and physiological changes related to metabolism (eg. radiolabelled glucose in the thyroid)	• Used to determine size and position (of foetus, organs)
• Can determine brain function	• Cannot determine brain function, as ultrasound cannot pass through bone, but good for soft tissue imaging
• Can tell difference between benign and malignant tumours	• No info on type of tumour

QWC ✓

Explain why the effective half-life of a radionuclide in a biological system is always less than the physical half-life.

[2 marks]

- Physical half-life is only dependent on the type of radioactive substance and therefore its physical properties ✓
- Effective half-life takes into account removal from the body ✓

The physical half-life of a radionuclide is 20 days. The nuclide was administered to a patient. Initially the corrected count rate at the patient's body was 2700 counts s^{-1}. Five days later, the corrected count rate at the same place on the patient was 1200 counts s^{-1}.

Calculate the biological half-life of the nuclide.

[4 marks]

$$\frac{1}{T_E} = \frac{1}{T_B} + \frac{1}{T_P}$$

T_E: effective half-life; T_B: biological half-life; T_P: physical half-life

$$A_t = A_0 e^{-\lambda t}$$

A_t: activity at a given time; A_0: initial activity; λ: decay constant; t: time

$$1200 = 2700e^{-5\lambda} \checkmark \Rightarrow -5\lambda = \ln\left(\frac{1200}{2700}\right)$$

$$\lambda = \frac{-1}{5}\ln\left(\frac{1200}{2700}\right) = 0.1622 \checkmark$$

$$T_E = \frac{\ln(2)}{\lambda} = \frac{\ln(2)}{0.1622} = 4.273 \text{ days}$$

$$\frac{1}{4.273} = \frac{1}{T_B} + \frac{1}{20} \checkmark \Rightarrow T_B = \left(\frac{1}{4.273} - \frac{1}{20}\right)^{-1} = 5.4340$$

biological half-life = 5.4 ✓ days

Table 1 gives the properties of two radionuclides.

Table 1

	Technetium 99 m	**Iodine 131**
emitted radiation	gamma	$beta^{-}$ and gamma
half-life / hours	6.0	190
energy of gamma ray / keV	140	610

By considering information in **Table 1** suggest which of these nuclides is more suitable for use as a tracer in medical diagnosis.

[4 marks]

Factor	Comments	Preferred?
Ionisation	Beta is more ionising, so ^{131}I does more damage ✓	Technetium 99m
Energy	^{131}I has gamma rays which are more than 4 times as energetic; ✓ difficulties with gamma camera	Technetium 99m
Half-life	^{131}I remains in the body for too long; could cause harm to others ✓	Technetium 99m
	$^{99}T^{m}$ half-life may be too short ✓	Iodine 131

Technetium 99m is more suitable ✓ 4 max.