

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 _____

Section B

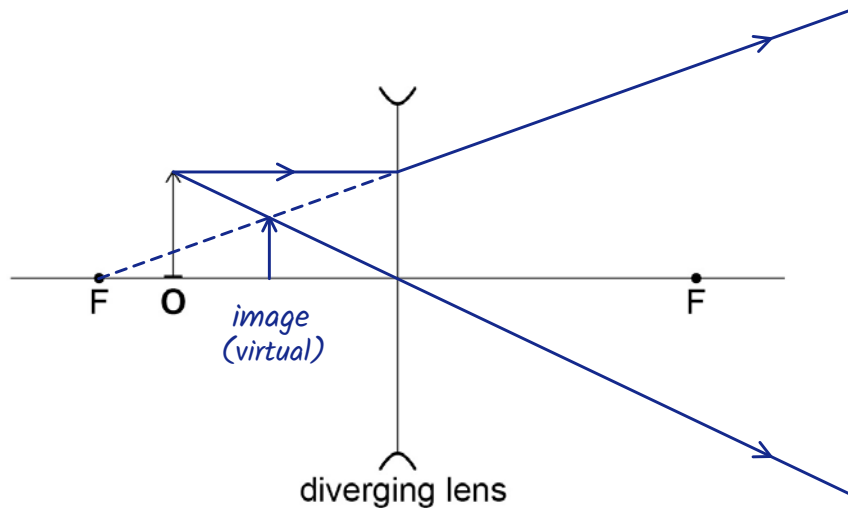
Answer **all** questions in this section.

- 0 1** . **1** 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 parallel to the principal axis pass after refraction by the lens.

Power is the reciprocal of focal length measured in metres.

- 0 1** . **2** 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]**



- 0 1** . **3** State the defect of vision that would be corrected using a diverging lens. **[1 mark]**

Myopia (short sight).

- 0 1 . 4** 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]

$$1/f = 1/u + 1/v$$

$$1/(-0.33) = 1/0.25 + 1/v$$

$$1/v = -3.03 - 4.00 = -7.03 \text{ m}^{-1}$$

$$v = -0.14 \text{ m (virtual image on the same side as the object)}$$

distance from lens to image = 0.14 m

- 0 1 . 5** 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.

[2 marks]

Each image must stimulate (activate) different cones,

and the cones stimulated by the two images must be separated by at

least one unstimulated cone.

Turn over ►

0 2 . 1 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]

The frequency of the vibrations does not change as the wave is transmitted through the ear.

The amplitude of the vibrations is reduced.

0 2 . 2 Explain how the components of the ear act to amplify the pressure changes due to the sound wave.

[3 marks]

The ossicles act as a lever system, which produces an increase in force (about 1.5 times) from the eardrum to the oval window.

The area of the oval window is much less than the area of the eardrum (about 15 to 20 times smaller).

Since pressure = F/A , the larger force acting on a much smaller area gives a large increase in pressure (amplified about 20 times).

0 2 . 3 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]

$$\text{intensity level} = 10 \log(I/I_0), \quad I_0 = 1.0 \times 10^{-12} \text{ W m}^{-2}$$

$$82 = 10 \log(I/I_0) \quad \text{so} \quad I/I_0 = 10^{8.2}$$

$$I = 1.0 \times 10^{-12} \times 10^{8.2} = 1.6 \times 10^{-4} \text{ W m}^{-2}$$

$$\text{intensity} = \underline{1.6 \times 10^{-4}} \text{ W m}^{-2}$$

- 0 2 . 4** 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.

[2 marks]

$$I = P / 4\pi r^2 \quad \text{so} \quad P = I \times 4\pi r^2$$

$$P = 1.6 \times 10^{-4} \times 4 \times \pi \times 2.0^2$$

$$P = 8.0 \times 10^{-3} \text{ W}$$

power = 8.0×10^{-3} W

Turn over for the next question

Turn over ►

0 3

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]

Patient safety: PET uses a radioactive tracer injected into the patient, so the patient receives a moderate to high dose of ionising radiation

(gamma photons from annihilation), which can damage cells.

Ultrasound is non-ionising, uses no tracer and has no known harmful effects, so it is much safer, e.g. for a foetus.

Convenience: PET needs pre-treatment (the tracer must be produced and injected and allowed to reach the organ), and the patient must lie still in a large, enclosed scanner for a long time (about 2 to 4 h in total), which is not good if they are claustrophobic. Ultrasound

needs no injection, only cold coupling gel on the skin, the scan takes about 10 to 15 minutes, and patient movement is tolerated.

Cost: a PET scanner is large, bulky and expensive (it needs a cyclotron nearby to make the tracer), whereas ultrasound equipment is relatively cheap and portable.

Information: PET shows chemical and physiological changes related to metabolism, so it is useful for detecting brain activity and the function of organs, and can provide information about malignancy and tumour spreading. Ultrasound shows size and position (and movement, e.g. of a foetus or organs) and is good for imaging soft tissues, but it cannot penetrate bone, so it cannot examine the brain, and cannot pass through air spaces such as the lungs. It cannot distinguish between benign and malignant solid masses.

0 4

1

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 depends only on the properties of the nuclide.

Biological removal (excretion) also occurs, so the nuclide is removed more quickly.

0 4

2

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 $2700 \text{ counts s}^{-1}$. Five days later, the corrected count rate at the same place on the patient was $1200 \text{ counts s}^{-1}$.

Calculate the biological half-life of the nuclide.

[4 marks]

$$A = A_0 e^{-\lambda t}, \text{ where } \lambda \text{ is the effective decay constant}$$

$$1200 = 2700 e^{-5\lambda} \quad (t = 5 \text{ days})$$

$$\lambda = \ln(2700/1200) / 5 = 0.811 / 5 = 0.1622 \text{ day}^{-1}$$

$$T_E = \ln 2 / \lambda = 0.693 / 0.1622 = 4.273 \text{ days}$$

$$1/T_E = 1/T_P + 1/T_B$$

$$1/4.273 = 1/20 + 1/T_B$$

$$1/T_B = 0.2340 - 0.0500 = 0.1840 \text{ day}^{-1}$$

$$T_B = 1/0.1840 = 5.4 \text{ days}$$

5.4

biological half-life = _____ days

Turn over ►

0 4 . 3 **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]

Technetium 99m is more suitable as a tracer.

Iodine 131 emits beta, which is more ionising than gamma, so it is more likely to damage cells and increases the dose.

Its 610 keV gamma rays are over 4 times more energetic than the 140 keV rays of Tc-99m, which causes problems when imaging with a gamma camera.

190 h is much longer than 6.0 h, so I-131 stays active in the body longer, a greater danger to the patient and others near them.

END OF QUESTIONS