TOPIC 33 Option M – *Medical Physics*

1 *(a)* Give an explanation of how the eye forms focused images of objects situated at different distances. Suggest why a swimmer cannot see clearly underwater unless goggles are worn. [5]

(b) A person is given a pair of spectacles fitted with bifocal lenses to correct the far point to infinity and the near point to 25 cm from the eye. One of the lenses has sections with powers of –0.25 dioptres and +2.0 dioptres.

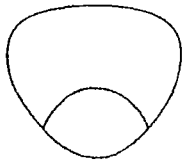

Fig. 1

(i) Copy out Fig. 1 and label each section of the lens with the value of its focal length. [3]

(ii) Calculate the positions of the far point and the near point of the unaided eye. [5]

(iii) Briefly discuss possible causes for this eye condition. [2]

J90/III/14

2 *(a)* Some types of radiation are more damaging to the human body than other types. Using alpha, beta, gamma and X-rays as examples, describe the relative effects of each. [7]

(b) "The effect of radiation on a human body depends not only on the total dose but also on how it is delivered. A dose that is delivered all at once (acute) is more dangerous than a dose spread out over a long period of time (chronic); a dose delivered to the entire volume of the body (whole body exposure) is more dangerous than a dose delivered to only some part of the body; a dose delivered to a radio-sensitive part of the body is more dangerous than a dose to a radio-resistant part."

The above paragraph is taken from an article called "Radiation and Life" by Hans C. Ohanian. Give possible reasons for the statements he makes. Include in your answer an example of a radio-sensitive and a radio-resistant part of the body. [8]

N90/III/13

3 *(a)* Describe the optical structure of the human eye and mention specifically the component which, in each case,

(i) controls the amount of light entering the eye,

(ii) is sensitive to light,

(iii) does most of the focusing,

(iv) adjusts the focus. [7]

(b) The pupil in a person's eye has a diameter of 6.0 mm. Calculate the angle of divergence of light entering the eye from a point on an object at distance 150 mm as shown in Fig. 2.

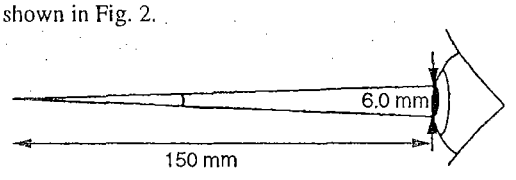

Fig. 2

The person then looks at a distant object. By what angle does the angle of divergence change? [3]

(c) An eye can focus clearly on objects between 120 mm and 250 mm away.

(i) What minimum power of spectacle lens is required to enable the eye to focus on objects at infinity?

(ii) What will be the range of distinct vision of the corrected eye? [5] N90/III/14

4 *(a)* Describe, using a diagram, a method of producing X-rays. [7]

(b) State an advantage of producing X-rays from a small area of the target electrode when an X-ray photograph is required. [1]

(c) What problem can arise as a result of using X-rays for taking photographs? How is the problem minimised both for the radiographer and the patient? [3]

(d) To examine internal structures within the body, ultrasound in the MHz frequency range can be used in order to overcome problems such as the one referred to in *(c)*.

(i) Why is very high frequency ultrasound needed?

(ii) Explain the principles of one method of producing ultrasound. [4]

J91/III/13

5 *(a)* A beam of parallel light, shown as solid lines, is approaching the cornea at the front of an eye as shown in Fig. 3. Draw a sketch of the diagram and show the refraction which takes place at the cornea and at each surface of the lens to form an image on the retina. [3]

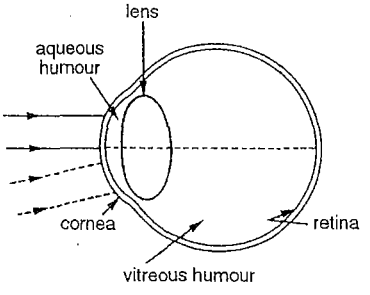

Fig. 3

(b) Also show on your sketch the path the light would take if, whilst still being parallel, it was approaching the eye at a small angle to the light in (a), as indicated by the broken lines in Fig. 3. [2]

(c) Draw another sketch to show the path of light to a focused image on the retina from a point object close to the eye. How does this sketch illustrate the property of accommodation? [2]

(d) Explain what is meant by the terms *short sight* and *astigmatism*. How may each of them be corrected by using spectacle lenses? [4]

(e) A man finds that he can focus clearly only on objects between 25 cm from the eye and infinity if he wears spectacles with lenses of power –2.5 dioptres.

(i) What type of lens is this?

(ii) What is the focal length of one of the lenses?

(iii) What range of vision does he have if he is not wearing his spectacles? [4]

J91/III/15

6 (a) Draw a labelled diagram of one type of modern X-ray tube. [5]

(b) Describe the desirable features of the image on an X-ray plate which is to be used for diagnosis. Explain how the X-ray beam is controlled to achieve these features. [10]

N91/III/13

7 (a) Draw a labelled diagram of the structure of the human middle ear. Hence, or otherwise, explain

(i) the purpose of the ossicles,

(ii) why pain is sometimes felt in the ear when ascending or descending rapidly. [8]

(b) The earpiece of a personal radio produces 0.4 μW of sound power. Given that the threshold intensity, I_0, is 1.0×10^{-12} W m^{-2}, estimate the intensity level

(i) at a distance of 1 m from the earpiece when the sound power is emitted uniformly in all directions,

(ii) in the auditory canal when the earpiece is correctly fitted.

Comment on your answers. [7]

N91/III/14

8 (a) Explain the principles of one method of generation of ultrasonic waves for use in medical diagnosis. [5]

(b) Compare the use of ultrasound with the use of X-rays in medical diagnosis. [10]

J92/III/13

9 (a) The loudness of a sound as heard by an individual depends on the frequency and intensity of the sound.

(i) Define *frequency* and *intensity*.

(ii) Sketch a graph to show how loudness of a sound, as heard by a person with normal hearing, depends on frequency when the intensity of the sound is constant. Point out any special features of the graph.

(iii) Describe the response of the ear to different intensities of sound with the frequency remaining constant. Hence define *intensity level*. [11]

(b) A source emits sound energy uniformly in all directions. A sound-level meter records 92 dB when situated 2.5 m from the source. Given that I_0 the threshold intensity of hearing, is 1.0×10^{-12} W m^{-2}, calculate the total sound power emitted by the source. [4]

J92/III/14

10 (a) Ionising radiations generally have harmful effects on the human body. Explain what is meant by the term *ionising radiation* and state what harmful effects may be caused. [3]

(b) Name four types of ionising radiation and briefly describe how the harmful effects of each type may be minimised. [6]

(c) When X-rays or ultrasound are used for imaging internal body structures, it is important to make visible as much detail as possible. In the following, choose either X-rays or ultrasound to illustrate your answer.

(i) Explain how changes can be made to increase the sharpness of images.

(ii) Explain how changes can be made to increase the contrast of images.

(iii) Describe how three-dimensional information can be obtained from two-dimensional pictures. [6]

N92/III/13

11 (a) Draw a labelled diagram to show the structure of the eye. [3]

(b) Explain, using additional diagrams where necessary,

(i) how the eye can adjust to form focused images of objects at different distances,

(ii) why it is not possible to see clearly when swimming under water unless goggles are worn,

(iii) why, even when you shut one eye, you are not aware of having a blind spot,

(iv) why the eye has a greater depth of focus in bright light than in dim light. [9]

(c) Explain what is meant by the term *astigmatism*. How may it be corrected by spectacle lenses? [3]

N92/III/14

12 A recent medical technique seeks to improve the vision of people who have had cataracts removed. A cataract operation involves the removal of the eye lens when it has

become too opaque for light to travel through it. In the past the patient has required very strong spectacle lenses, which produce a distorted image, making seeing difficult, particularly when only one eye has been treated. The new technique uses a donor cornea, which is first frozen and then shaped. It can be stitched on to the patient's own cornea and becomes an extra, living, contact lens, replacing the original eye lens which has had to be removed.

Answer the following questions concerning this operation.

(a) Draw a ray diagram showing the formation of an image on the retina of a normal eye. (You are NOT expected to draw a full diagram of the structure of the eye. Apart from the light rays, show only the cornea, the lens and the retina.) [4]

(b) Draw a corresponding diagram to the one in *(a)* showing what will happen to the rays when the eye lens has been removed. Explain what the patient would see. [2]

(c) Illustrate how the patient can again see objects clearly in focus by use of the donated cornea. [3]

(d) Why would the patient have a problem with visual accommodation after this operation? How would this problem be overcome? [4]

(e) Suggest two reasons why the donor cornea has to be frozen. [2]

J93/III/13

13 *(a)* Describe the basic structure of the ear and explain how the ear responds to an incoming sound wave. [8]

(b) The average intensity of sound from a quiet con-versation is 5.0×10^{-6} W m^{-2}; the threshold intensity is 1.0×10^{-12} W m^{-2}.

Answer the following questions about this statement.

(i) What is meant by the term *intensity* when applied to a sound wave? [1]

(ii) What does the term *threshold intensity* mean? [1]

(iii) How would you measure the *average* intensity, given that you have a sound-level meter? [2]

(iv) What is the intensity level, in dB, of the quiet conversation? [3]

J93/III/14

14 *(a)* (i) Describe the effects of ionising radiation on the cells of living matter. [3]

(ii) Hence explain why, when assessing a radiation hazard, the following factors must be taken into consideration:

(1) type of radiation,
(2) dose rate,
(3) total dose. [6]

(b) Compare the uses of ultrasound and X-radiation for obtaining diagnostic information about structures within the body. [6]

N93/III/13

15 *(a)* The *threshold intensity* of hearing is taken to be 1.0×10^{-12} Wm^{-2} at 1.0 kHz for the average person with no hearing defect.

(i) What is meant by *threshold intensity*?

(ii) Explain why the frequency at which this intensity is measured should be specified. [4]

(b) (i) By reference to the range of intensities which can be detected by the ear, explain the significance of the logarithmic response of the ear to intensity.

(ii) Write down an equation defining intensity level I in terms of the threshold intensity I_0 explaining any other symbols used. [6]

(c) The sound energy incident on a person's eardrum may be assumed to have been collected over an area of 1.0 cm^2. Calculate the total sound energy incident on the eardrum if the person attends a disco for 3.0 hours where the average intensity level is found to be 105 dB. Comment on your answer. [5]

N93/III/14

16 *(a)* Describe the mechanisms by which radiation causes damage to the cells of living matter. Hence explain the probable effects on a cell of such damage. [7]

(b) On the basis of your account in *(a)*, explain why the extent of radiation damage depends on

(i) the type of radiation to which the cells are exposed,

(ii) the total dose of radiation,

(iii) the dose rate of the radiation. [8]

J94/III/13

17 A student complains that he is not able to see clearly any object unless it is more than 75 cm from his eyes. The normal near point is taken as being 25 cm from the eye.

(a) (i) Name the student's eye defect.

(ii) State what is meant by the *near point* of the eye. [2]

(b) (i) Copy Fig. 4 on to your answer sheet.

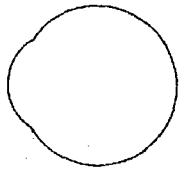

Fig. 4

On this, draw a ray diagram to illustrate the paths of two rays of light from a point object at the normal near point, showing how they would reach the retina of the student's eye.

(ii) Draw a second ray diagram to show how a lens may be used to correct the defect for an object set at 25 cm from the eye.

(iii) Calculate the power of this correcting lens. [9]

(c) Some animals are able to change the curvature of the cornea so that they are able to see clearly both in air and in water. Explain why a change in curvature is necessary. [4] J94/III/14

18 Write an article about medical imaging. You should describe two methods of imaging and should refer to the principles of the method described, to any possible danger from the process, and to steps taken to minimise this danger. Comment should also be made about the clarity of the images produced and the factors which affect clarity. [15] N94/III/13

19 (a) Describe how the eye of a normally sighted young person can form focused images from objects at different distances. [3]

(b) Describe what is meant by the term *depth of focus*, as applied to the eye. Draw a diagram to illustrate your answer. [4]

(c) Use the diagram you have drawn in (b) to suggest how the depth of focus varies with the brightness of the light. Note: when viewing objects in bright light, the iris reduces the size of the pupil and hence reduces the aperture of the eye. [3]

(d) An old person has little accommodation when viewing objects at different distances. He can see objects which are a long distance away clearly but needs several different spectacles for viewing objects at other distances.

(i) Draw a diagram to show how spectacles enable him to see closer objects more clearly.

(ii) Calculate the power of the spectacles he needs for viewing

(1) television at a distance of 3.0 m,

(2) a book at a distance of 0.40 m. [5] N94/III/14

20 (a) With the aid of a labelled diagram, give a description of the way in which X-rays are produced. [5]

(b) How can

(i) the sharpness,

(ii) the contrast,

be controlled in X-ray imaging? [6]

(c) How can the harmful effects of X-rays be minimised when making X-ray images of patients? [4] J95/III/13

21 (a) Discuss why it is necessary to consider

(i) the type of radiation,

(ii) the dose-rate of radiation,

when assessing the risk caused by exposure to ionising radiation. [6]

(b) In order to obtain a correctly exposed X-ray film, the accelerating voltage V and the filament current I of an X-ray tube may be varied, together with the exposure time t.

At a particular point in air, the X-ray beam exposure E is given by the expression

$$E = kV^2It,$$

where k is a constant.

(i) Explain, in terms of physical principles, why X-ray exposure depends on filament current.

(ii) In order to obtain an X-ray film of the chest of an average-sized patient, the tube voltage is adjusted to 70 kV and the tube current to 450 mA. What changes would you make to obtain a correctly exposed X-ray film of the chest of a very fat person, bearing in mind the need to keep radiation risk to a minimum? [9] N95/III/13

22 (a) (i) What is meant by the term *depth of focus*?

(ii) Explain why the depth of focus of the eye changes as the intensity of light incident on the eye changes. [5]

(b) A certain elderly person can see clearly objects which are situated between 1.5 m and 10 m from his eyes.

Calculate the power of the lens which will enable him to see clearly objects which are

(i) very distant,

(ii) situated 25 cm from his eyes. [5]

(c) In order to avoid having to use two pairs of spectacles, the person described in (b) may be given bi-focal lenses. One such lens is illustrated in Fig. 5.

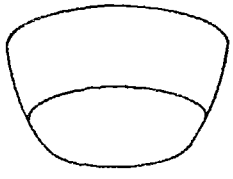

Fig. 5

The upper region has a different focal length from that of the lower region. State and explain which region of the lens will be used tor reading [2]

(d) (i) What is meant by *astigmatism*?

(ii) Explain why, when correcting astigmatism by means of a lens, the orientation of the lens with respect to the eye is important. [3] N95/III/14

23 (a) (i) Outline the use of magnetic resonance to obtain diagnostic information about internal structures of the human body.

(ii) Give two advantages of the use of magnetic resonance imaging (MRI) over the use of X-rays for diagnostic purposes. [7]

(b) (i) What is meant by the *loudness* of a sound?

(ii) Explain why loudness is more directly related to the intensity level, rather than the intensity, of a sound wave.

(iii) A small buzzer produces an intensity level of 65 dB at a distance of 2.0 m. Assuming that the buzzer emits sound uniformly in all directions, calculate the power of the sound produced by the buzzer. State one other assumption which you make. [8] J96/III/11

24 (a) Describe what is meant by the term *ionising radiation*. [3]

(b) Explain why a short burst of high intensity radiation is more dangerous to body cells than the same dose delivered over a longer period of time by the same radiation of low intensity. [4]

(c) What may be the outcome of the exposure of living cells to ionising radiation? [3]

(d) Suggest why children, and particularly unborn children, may be more susceptible to damage from ionising radiation than adults. [2]

(e) How does the type of radiation (α, β or γ) affect the location of the possible damage which ionising radiation may cause in a person? [3]
N96/III/13

25 (a) Describe what is meant by the term *ultrasonic* waves. Are these waves longitudinal or transverse waves? State a typical frequency of an ultrasonic wave which has medical applications. [3]

(b) Explain the principle of the generation of ultrasonic waves using piezo-electric transducers. [4]

(c) The use of ultrasonic waves in medical diagnosis is dependent on the differential *transmission* and *reflection* of the waves as they pass through different parts of a body. Describe how these factors differ for ultrasonic waves which are travelling across boundaries of

(i) air to skin,

(ii) tissue to water,

(iii) tissue to bone. [8] N96/III/14

26 (a) Outline the physical principles of the following techniques to obtain diagnostic information about the internal structure of a human body.

(i) X-rays, [4]

(ii) magnetic resonance. [5]

(b) State one disadvantage of each of the methods of imaging described in (a). [2]

(c) Explain the principle of one method of producing ultrasonic waves. [4]
J97/III/11

27 (a) (i) Outline the use of ultrasound to obtain diagnostic information about internal structures of the human body.

(ii) The risk factor associated with the use of X-rays for diagnostic purposes is considered to be much greater than that for the use of ultrasound. Suggest **two** reasons why X-rays may, however, be preferred for diagnosis. [7]

(b) (i) The earphone of a personal radio produces 6.0 μW of sound power. Estimate the intensity level of the sound at the ear when

1. the earphone is in the ear canal so that all of the sound power is incident on the eardrum of area 50 mm^2.

2. the earphone is held 800 mm from the ear and the sound power is emitted uniformly in all directions.

(ii) Health warnings have been issued with regard to the use of personal radios. By reference to your answers in (i), comment on whether these warnings are justified. [8]
N97/III/11

28 (a) Outline the use of ultrasound to obtain diagnostic information about internal structures. [5]

(b) Give two advantages and two disadvantages of the use of ultrasound in diagnosis compared to the use of magnetic resonance imaging. [4]

(c) (i) A person with defective vision cannot see clearly objects which are closer than 1.4 m from his eyes. Estimate the power of the lenses required so that the person can read normally.

(ii) Explain why a swimmer with normal vision cannot see clearly underwater unless goggles are worn. [6] J98/III/11

29 (a) Give a detailed account of one method of medical imaging, other than X-rays. Your account should cover the principles of creating the image and the advantages your chosen method has over X-ray imaging. [7]

(b) Explain, with reference to the structure of the ear, how it responds to an incoming sound wave. [4]

(c) The ear is said to have a *logarithmic response* to intensity.

(i) Explain what this expression means.

(ii) Calculate the intensity level of a sound of intensity 5.1×10^{-5} W m^{-2}, given that the threshold intensity is 1.00×10^{-12} W m^{-2}. [4]
N98/III/11

30 (a) X-rays are used for imaging internal body structures.

(i) State two factors which affect the contrast of the image produced on an X-ray plate.

(ii) The attenuation in matter of a parallel X-ray beam may be represented by the expression

$$I = I_0 e^{-\mu x}$$

1. State what is meant by *attenuation.*
2. State and explain what change occurs in the constant μ when the X-ray beam passes from muscle into bone. [5]

(b) Briefly describe the use of a laser in

(i) clinical therapy as a scalpel,

(ii) pulse oximetry. [6]

(c) The intensity of sound at a certain position is 2.9 mW m^{-2}.

(i) Calculate the intensity level of this sound.

(ii) Comment on the loudness of the sound as experienced by a person with normal hearing when the frequency of the sound increases gradually from 3 kHz to 12 kHz. [4]

J99/III/11

31 *(a)* With the aid of diagrams, explain how the eye forms focused images of objects at different distances. [6]

(b) Two sounds have the following characteristics,

sound A frequency 14 kHz, intensity 7.0×10^{-6} W m^{-2}

sound B frequency 2.0 kHz, intensity 4.0×10^{-6} W m^{-2}.

(i) Explain why sound B is likely to be louder even though it has a lower intensity.

(ii) Calculate the intensity level of sound A. [5]

(c) Describe an example of the use of radioactive tracers in medical diagnosis. [4]

N99/III/11

32 *(a)* Briefly outline one use of each of the following in medical diagnosis.

(i) X-rays

(ii) lasers [6]

(b) (i) Explain how the eye forms focused images of objects which are at different distances from the eye.

(ii) Estimate the change in optical power of the eye when the eye focuses firstly on a point 30 cm from the eye and then on a distant star. [5]

(c) (i) Define *intensity level* for a sound of intensity *I.*

(ii) A student states that intensity level is a measure of the loudness of a sound. Comment briefly on whether this statement is correct. [4]

J2000/III/11

33 *(a)* Outline the physical principles of the method for the production of X-rays in a hospital X-ray department. [3]

(b) The intensity of a parallel beam of X-rays as it enters a person's thigh is 0.030 W cm^{-2} and the absorption coefficient μ for muscle is 0.23 m^{-1}. Calculate the intensity of the emerging beam where the beam has penetrated a distance of 0.14 m through muscle only. [4]

(c) Explain why radiographers need to be able to change the voltage used in the production of X-rays. [3]

N2000/III/15

34 *(a)* Explain how the ear responds to an incoming sound wave. [4]

(b) Suggest how the logarithmic response of the ear to sound affects hearing. [2]

(c) (i) Sketch a graph showing how the sensitivity of the ear of a young person with normal hearing varies with the frequency of the sound. [2]

(ii) Add to your sketch two other labelled graphs showing how the sensitivity may very well be different,

1. for an older person, (label this line O)
2. for someone who is appreciably deaf, (label this line D). [2]

N2000/III/16