Answers

1.1

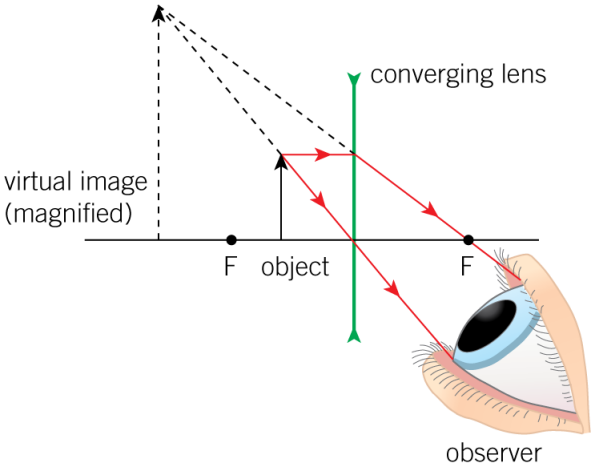
4 a 4 μm

1.2

1 a i The top ray should refract at the lens and pass through F; the bottom ray should refract at the lens and then become parallel to the principal axis; the image should be formed at 1.4(3)*f* on the right-hand side of the lens.

ii real, inverted, diminished

b i



ii virtual, magnified, upright

2 a and **c** $v = +0.240$ m

b i real

ii inverted

3 a and **c** $v = -0.300$ m

b i virtual

ii upright

4 a $v = -0.086$ m, image height = 5.7 mm

b $v = -0.111$ m, image height = 4.4 mm

1.3

1 b ii −0.125 D

2 b ii +2.0 D

3 a i –0.20 D

ii 0.26(3) m

b i +2.75 D

ii 0.36(3) m

2.1

3 **a** 1.0×10^{-9} N

b 5.0×10^{-4} Pa

2.2

1 **a** 2.2×10^{-2} W m^{-2}

b 103 dB

2 2.0 W m^{-2}

3 **a** 70 dB

b 3.2×10^{-6} W m^{-2}

4 **a** 1.6×10^{-2} W m^{-2}

b 105 dB

2.3

2 **b** **i** 20 dBA; 40 dB

ii 60 dBA, 0 dB

iii 15 dBA, approx 45 dB

3.1

1 173 kJ

3 **b** **i** 0.90 mV

ii 0.89 mV

4.1

1 **a** **i** 0.14 mm

ii 0.62 mm

2 **b** **ii** about 0.15 m

3 **a** **i** 0.999

ii 1.66×10^{-3}

c **i** 1.64×10^{6} kg m^{-2} s^{-1}

ii 2.3×10^{-5}

4.2

1 **b** **ii** 75.4°

4 **b** **i** 23.3°

ii 33.8°

4.3

1 Hydrogen nuclei possess a magnetic moment which causes each nucleus to precess in a magnetic field in one of two closely spaced energy levels. The nuclei can be excited into the higher energy state using radio waves of the same frequency as the precession frequency.

An excited nucleus emits a radio wave photon when it de-excites enabling the position of the nucleus to be located OR all parts on the human body contain hydrogen nuclei in molecules and therefore can be scanned using an MR scanner.

2 **a** A pulse of radio waves is applied in order to excite the hydrogen nuclei at the location in the patient where the magnetic field is such that the precession frequency of the nuclei is equal to the radio wave frequency.

b **i** The location of the overall (or resultant) magnetic field is changed systematically so that the field excites the hydrogen nuclei at each location systematically.

3 **a** Without excitation, there are more hydrogen nuclei precessing in the lower energy state than in the higher energy state. When a nucleus is excited by absorbing a radio wave photon, the alignment of the nucleus changes from precessing about the direction of the field to precessing about the opposite direction.

b After each radio wave pulse is applied, a short pulse of radio waves is emitted by the excited hydrogen nuclei when they de-excite so an alternating emf is induced in a radio wave detector.

4 **a** The rate of decay of a detected signal (i.e., the relaxation time) depends on the type of molecules surrounding the water molecules containing the de-excited hydrogen nuclei.

b **i** An MR scan uses radio waves which are non-ionising whereas X-rays are ionising and therefore harmful.

ii An MR scan can distinguish between hard and soft tissues as well as between different types of soft tissues whereas ultrasound cannot distinguish between hard and soft tissue.

5.1

3 **b** **i** 1.1×10^{-14} J

ii 1.7×10^{-19} Hz, 1.8×10^{-11} m

4 **a** 2500 W

b **i** 25 W

ii 2475 W

5.2

1 **b** **i** 46 m^{-1}

ii 37%

2 **a** **i** 1.0×10^{-2} W m^{-2}

ii 4.0×10^{-5} J s^{-1}

b 2.0 mm

3 **b** 21 mm

5.3

1 a i A contrast medium makes the image of certain organs stand out. This is because the contrast medium is a good absorber of X-rays so the X-rays that reach an organ do not pass through it. As a result, a clear shadow of the organ is seen on the detector.

ii A barium meal given to a patient before an X-ray image of the stomach is taken makes the image of stomach stand out. A solution containing iodine (in a compound) makes blood vessels stand out.

b A lead collimator grid is a series of parallel narrow channels through a lead block. The grid is placed between the patient and the detector in order to prevent X-rays scattered by tissue and bone in the patient from reaching the film. Scattered X-rays would 'fog' the film in the shadow areas, reducing the contrast between clear and dark areas of the film. Only X-rays that have not been scattered pass through the channels in the grid to reach the film.

2 a i lead

ii copper or tin

b The filter absorbs low energy X-rays which would otherwise be absorbed by the body. The metal needs to have a high atomic number as such metals absorb low energy X-rays more effectively than metals with a low atomic number. They would not be suitable as beam definers because they do not absorb high energy photons as effectively as lead.

3 a An intensifying screen is used to increase the rate of darkening of a photographic film and thereby reduces the duration of exposure (i.e., the exposure time) to X-rays. It consists of a double-sided film sandwiched between two sheets of fluorescent material such as calcium tungstate or zinc sulphide. The fluorescent material absorbs X-rays and re-emits many light photons for each X-ray photon absorbed.

b An image intensifier enables the radiation dose to be reduced by a factor of 1000 compared with an intensifying screen. It also enables a 'real time' image to be observed and recorded where observation of an organ in action (e.g., swallowing) is necessary.

4 a An ordinary X-ray imaging system consists of a fixed X-ray tube with an adjustable beam definer used to adjust the width of the X-ray beam so the beam irradiates the target area of the patient. The X-ray image is obtained by placing a detector or an encased photographic film in the path of the beam after it has passed through the patient. A CT scanner consists of an X-ray tube and a ring of thousands of small solid-state detectors linked to a computer. The patient lies stationary on a bed which is suitably positioned along the axis of the ring. The X-ray tube automatically moves round the inside of the ring, turning as it moves so the X-ray beam is always directed at the centre of the ring. The detector signals are simultaneously recorded by the computer each time the X-ray tube moves round the ring. In this way, the computer collects sufficient data to display a cross-sectional image of the patient.

b A CT scanner gives a digital image that can be enhanced electronically to make it sharper and clearer and can give a three-dimensional image of an organ. An ordinary X-ray image on a photographic film cannot be enhanced electronically and cannot be used to reconstruct a three-dimensional image.

6.1

1 a ii 6.0 hours

6.2

1 a 3.1×10^{-13} m

b 33%

2 100 kV X-rays from an X-ray tube could not be collimated into a single narrow beam of sufficient intensity whereas the X-rays from an electron accelerator can be. So the X-rays from an X-ray tube would affect other tissue and would require longer exposure which damages other tissue even more.

3 The X-rays from the electron accelerator can be switched on or off unlike gamma rays from a radioactive source. The electron accelerator does not need to be shielded when it is off unlike a gamma source.

4 The X-rays from an electron accelerator are in a narrow beam which would be unable to irradiate a defined area of the body effectively whereas X-rays from an X-ray tube can be used to irradiate a defined area.