

## IMAGING TEST

NAME.....

Take the velocity of light  $c = 3 \times 10^8 \text{ ms}^{-1}$ , and speed of sound as  $340 \text{ ms}^{-1}$

1.(a) Which of the following is the best estimate for the wavelength of red light?

$10^{-10} \text{ m}$ ,  $10^{-7} \text{ m}$ ,  $10^{-4} \text{ m}$ ,  $10^{-2} \text{ m}$

$10^{-7} \text{ m}$

(1)

(b) An x-ray beam has waves of wavelength  $1 \times 10^{-9} \text{ m}$ .

(i) Are these waves longitudinal or transverse?

transverse

(1)

(ii) What is the frequency of the waves?

$$v = f\lambda$$

$$f = \frac{3 \times 10^8 \text{ m s}^{-1}}{1 \times 10^{-9} \text{ m}}$$

$$f = 3 \times 10^{17} \text{ Hz}$$

(2)

(iii) What is the time duration of one wave?

$$T = 3 \times 10^{-18} \text{ s}$$

(c) Why are x-rays particularly suitable in the detection of bone fractures?

x-rays pass through flesh but are absorbed by bone hence creating shadows

(2)

(d) An x-ray photograph film is of size 400 mm by 300 mm and contains light sensitive grains of size 4mm across.

(i) How many pixels are there on the film?

$$100 \times 75 = 7500 \text{ pixels}$$

(1)

(ii) What is the smallest size of feature that can be resolved on the film?

$$4 \text{ mm} \times 4 \text{ mm}$$

(1)

(iii) Each pixel on the film stores one bit of information. How many bits of information can be stored on the film?

$$7500 \text{ bits}$$

(2)

2. A radio station transmits signals at a wavelength of 650 kHz. Calculate the wavelength of the signal.

$$v = f\lambda$$

$$\lambda = \frac{3 \times 10^8 \text{ m s}^{-1}}{6.5 \times 10^5 \text{ Hz}}$$

$$\lambda = 460 \text{ m}$$

(2)

3. An ultra-sound echo locator sends out pulses of waves of frequency 40 kHz lasting for 75 ms into a material in which the waves travel at  $1600 \text{ m s}^{-1}$ . An echo from a fault in the material is obtained 300 ms after being sent out.

(i) How many waves will be in each burst of signal?

$$40 \times 10^3 \text{ Hz} \times 75 \times 10^{-3} \text{ s} = 3000 \text{ waves}$$

(2)

(ii) What is the depth of the fault in the material?

$$\text{distance} = \text{speed} \times \text{time}$$

$$\text{distance} = 1600 \text{ m s}^{-1} \times 0.3 \text{ s} = 480 \text{ m}$$

so distance to fault = 240 m

(2)

(iii) What is the smallest limit of depth detection by this wave process?

pulse lasting 75 ms travels 480 m in 300 ms so smallest distance between pulses is 120 m so smallest depth is 60 m

(2)

4. A book contains 200,000 words. Each word has an average of 6 characters and each character needs 1 byte of memory storage.

(a) If stored in digital form, how much memory does the book require?

$2 \times 10^5 \text{ words} \times 6 \text{ ch/word} \times 1 \text{ byte / ch} = 1.2 \times 10^6 \text{ bytes}$

(1)

(b) How long would it take to transmit the book to a disc at a rate of 1 Mbit per second?

$1.2 \times 10^6 \text{ bytes} = 8 \times 1.2 \times 10^6 \text{ bits} = 10^7 \text{ bits}$

so at 1 Mbit per second it would take 10 seconds

(2)

5. In image processing a sharp edge to a picture needs smoothing to make the edge less abrupt. Explain how this can be done.

The image is converted into a series of pixels each with a numerical value

the value of each pixel is replaced with the mean of its neighbours, this softens abrupt changes in colour or shade.

(2)

6. A convex lens forms a clear image of a distant object on a screen 25 cm from the centre of the lens.

(i) Will the image be larger, smaller or the same size as the object?

smaller

(1)

(ii) What is the curvature of the waves going into the lens?

zero curvature = plane waves from a distant object

(1)

(iii) What curvature does the lens add to the incoming wave?

final curvature =  $1000 / 250 \text{ mm} = 4 \text{ D}$

(2)

(iv) What is the focal length of the lens?

250 mm

(1)

(v) What is the power of the lens?

4 D

(2)

(vi) The object is now brought closer to the lens. Which way must the lens be moved relative to the screen to bring the image back into focus?

moved away from the screen

(1)

7. A convex lens of power +10 D is placed 30 cm from an object of height 3 cm.

(i) Find the position of the image relative to the lens.

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$$
$$\frac{1}{v} = \frac{1000}{-300 \text{ mm}} + 10 \text{ D}$$
$$\frac{1}{v} = -3.3 \text{ D} + 10 \text{ D} = 6.7 \text{ D}$$

$$v = 149 \text{ mm}$$

(3)

(ii) What is the magnification factor of the lens for this image position?

$$\text{magnification} = \frac{v}{u}$$

$$m = \frac{149}{300} = 0.5$$

image will be half height of object

(2)

(iii) The object is now placed 10 cm from the lens. Where will the image of the object be formed?

a long way off – object is at focus of lens

(1)