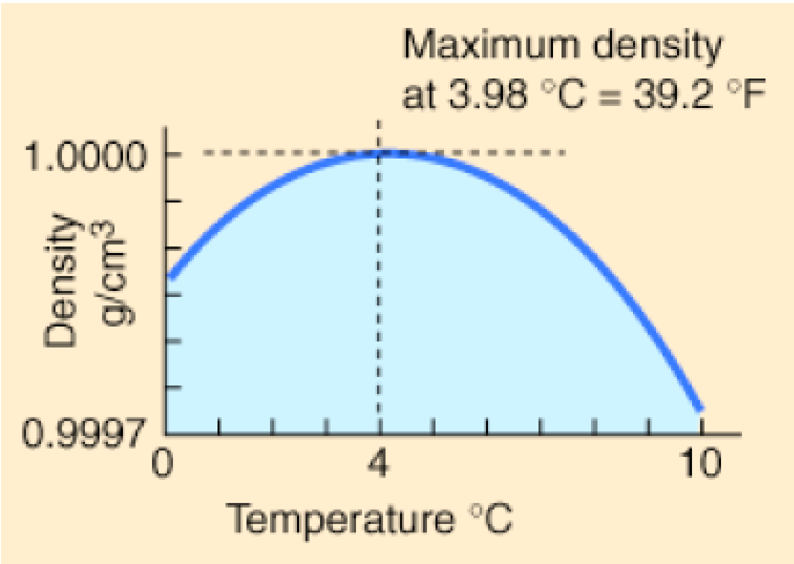
Answers 09

Question 1 (12 marks)

(a) The maximum density of water is at 4°C. 1 value

or diagram



1 ice floats

This means that ice floats and water at 4 °C pools at the bottom of frozen rivers and lakes, allowing water creatures to survive underneath the ice. 1

(b) The work needed to expand the spherical cavity from sphere with radius r to sphere with radius r + dr has two terms: 1

$\gamma dA = \gamma 8\pi r dr$ 1

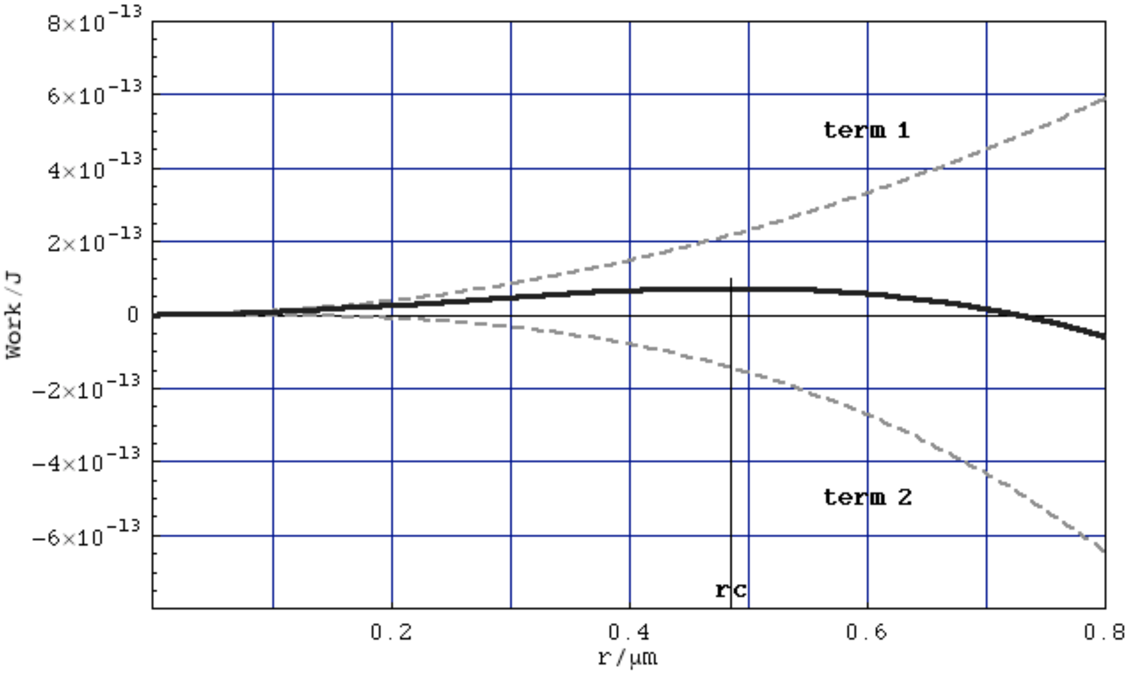
$PdV = -P4\pi r^2 dr$

$dW = 4\pi r(2\gamma - Pr)dr$ 1

term 1: total surface free energy, term 2: work against –P

Once dW/dr becomes negative, the cavity will spontaneously expand. This happens at r_c, where the slope of the continuous curve is zero: ~4.8 x 10^{-7} m. 1 (or diagram)

$$P = \frac{2\gamma}{r_c} = \frac{2 \times 72.8 \times 10^{-3}}{4.8 \times 10^{-7}} = 0.3 \text{ Mpa}$$ 1



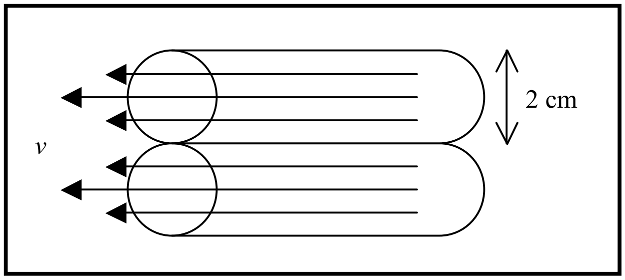
The columns of water in the xylem vessels of plants develop such bubbles, which grow and block the vessel. This is called cavitation. **1**

(c) The pressure is generated by the menisci in the interstices of the cell wall in the leaf tissue. **1**
The pressure of 0.3 MPa corresponds to curvature with r = 4.8 x 10^{-7} m (Young – Laplace law). **1**

The negative sign arises as the more dense medium (water) is on the concave side of the curvature. **1**

Question 2 (12 marks)

(i)



1

(ii) Flow rate Q = 5 litre.s^{-1} = $5 \times 10^{-3} m^3.s^{-1}$. The cross sectional area is $2\times\pi\times r^2$ (2 nostrils) = $2\times\pi\times 0.01^2 = 6.3\times10^{-4} m^2$.

$\bar{v}$ = Q/area = $5 \times 10^{-3} m^3.s^{-1} / 6.3\times10^{-4} m^2 = 8\ m.s^{-1}$ 1

(iii) Assuming non-turbulent flow, use Poiseuille's equation for one nostril:

$$\Delta P = \frac{8\eta\ell Q}{2\pi r^4} = \frac{8\eta\ell\bar{v}2\pi r^2}{2\pi r^4} = \frac{8\eta\ell\bar{v}}{r^2}$$ 1

$$= \frac{8\times1.005\times10^{-3}\times2.0\times8}{0.01^2} = 1.29\text{ kPa}$$

As the two nostrils are identical, same pressure difference across both nostrils 1

(iv) $\Delta P = \frac{8\eta\ell\bar{v}}{r^2} = \frac{8\times2.5\times2.0\times8}{0.01^2} = 3.2\text{ MPa}$!!

This is why you do not see elephants squirting custard! 1

(v) $N_R = \frac{\bar{v}\rho r}{\eta} = \frac{8\times10^3\times0.01}{1.005\times10^{-3}} = 80000$ 1

This is greater than 3000, very turbulent! Therefore, answer (iii) is an underestimation. 1

For custard: $N_R = \frac{\bar{v}\rho r}{\eta} = \frac{8\times10^3\times0.01}{2.5} = 30$ 1

This is not turbulent.

(b)

$$\Psi_{cell} = P - RTc_{cell} = 0.2 - 0.00831 \times 300 \times .3$$ 1
$$= 0.2 - 0.748 = -0.549$$
$$\Psi_{solution} = -RTc_{medium} = -0.00831 \times 300 \times .1 = -.249$$ 1

The water potential of the solution is higher (less negative), so water will flow into the cell to achieve new equilibrium. As the wall is not very stretchy, the volume will change little, so RTc_{cell} will remain the same (approximation), but the turgor pressure will rise:

1

$$\Psi_{cell} = \Psi_{solution} = -.249$$
$$= (0.2 + \Delta P) - 0.748$$
$$\Delta P = 0.748 - 0.2 - 0.249 = 0.299\text{MPa}$$

1

$$\Psi_{cell}(\text{final}) = -0.249\text{MPA}$$
$$P_{final} = 0.2 + 0.299 = 0.499\text{MPa}$$

<u>Question 3 (12 marks)</u>

(i) $\beta = 10\log\frac{I}{I_0}$ in decibels (dB) , $I_0 = 10^{-12}$ W.m^{-2}

$$I_{20} = 10^{2} \times 10^{-12} = 10^{-10}\,\mathrm{W.m^{-2}}$$ 1

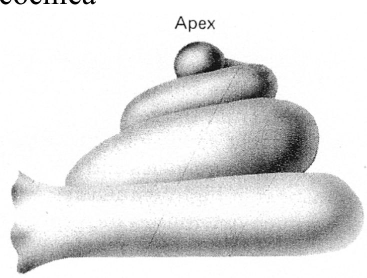
$$I_{80} = 10^{8} \times 10^{-12} = 10^{-4}\,\mathrm{W.m^{-2}}$$

$$\frac{I_{80}}{I_{20}} = 10^{6}$$

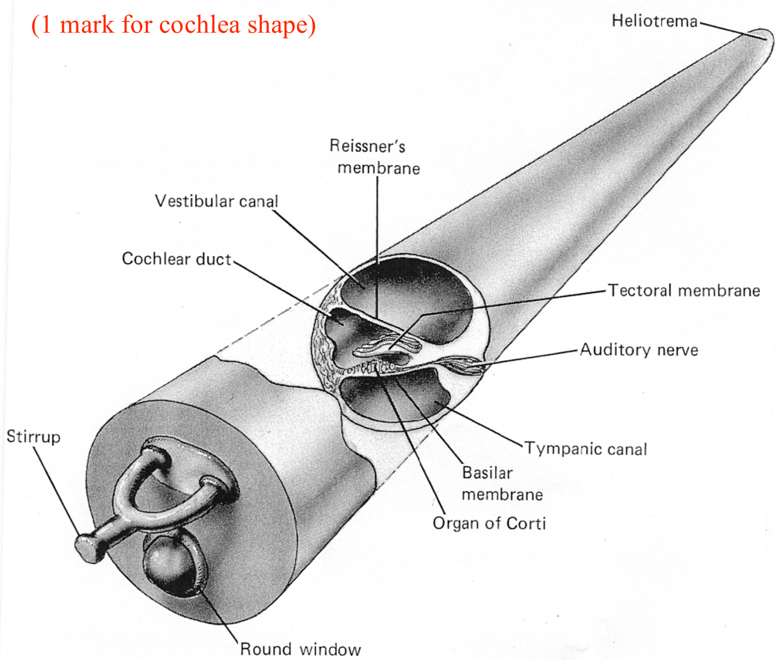
This is the difference in intensity for the two signals at each frequency

(ii) While the ear perceives huge range of intensities, there are frequency limitations. 20 Hz is the lower limit for the frequency response and the student will not hear the 20 dB signal and only just hear the 80 dB signal. At 1 kHz, the response is near frequency optimum and the student will hear both signals: 20 dB signal is at "quiet room" level, while 80 dB signal at "loud radio or a class lecture" level. 2

(c) The inner ear: cochlea



(1 mark for cochlea shape)



The vibration of oval window (1 mark) causes waves in the fluid in the cochlea, whose width and stiffness varies (1 mark), so maximal displacement occurs at different places for different frequencies: high frequencies near the window (1 mark), low frequencies at the other end (1 mark). Hair cells in the organ of corti (1 mark) respond to motion of basilar membrane by action potentials, each is connected to a nerve (1 mark), so pitch is coded by place on the cochlea (1 mark). The rate of excitation is also important (1mark).

Question 4 (12 marks)

(a) Applying the reduced eye equation:

$$\frac{n_1}{o} + \frac{n_L}{i} = \frac{n_L - n_1}{R}$$

$$\frac{1}{\infty} + \frac{1.333}{i} = \frac{1.333 - 1.0}{0.5}$$

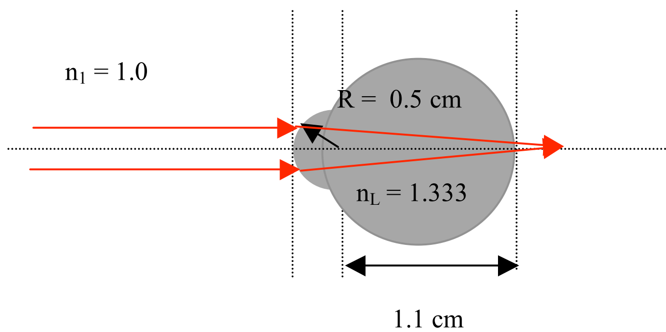
$$i = 2.0 \text{ cm}$$

1 correct equation

1 correct substitution

The image is focused 2.0 – (1.1 + 0.5 = 1.6) = 0.4 cm behind the retina at the back of the eye.

1 for position



1 for diagram

The laser can shave off some of the cornea to reduce R.

$$\frac{n_L}{i} = \frac{n_L - n_1}{R}$$

$$i = 1.1 + R$$

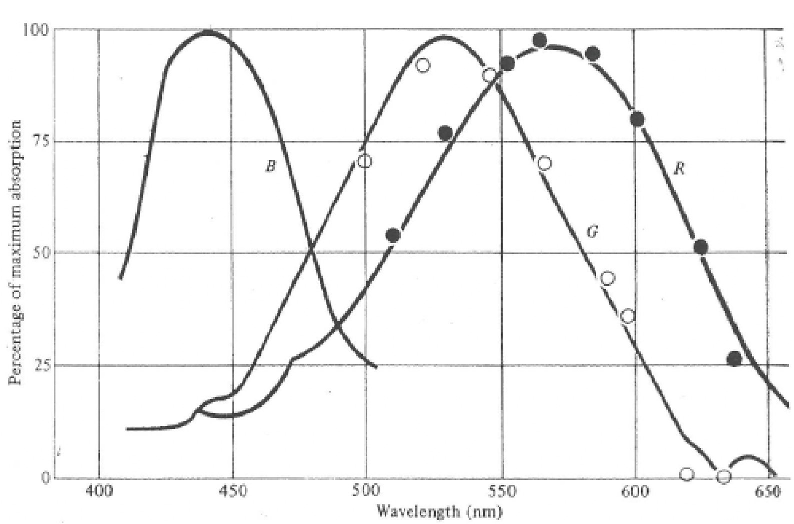
$$\frac{1.333}{1.1 + R} = \frac{0.333}{R}$$

$$R = 0.38 \text{ cm}$$

2 correct equations

(b) The sensation of colour is evoked by sufficient number of photons hitting the cone receptors in the retina at the back of the eye. The colour depends on the wavelength of light: blue 450 – 500 nm, green 500 – 570 nm, yellow 570 -590 nm, red longer than 610 nm. Humans have three types of cones, each senses range of wavelengths, centered on red, blue and green. The red and green cones are located on the fovea, while the blue are distributed over the back of the eye.

1 wavelengths of light



1 3 types of cones

1/2 cone response to colour

1/2 cone disttribution

(b) The illusion is created primarily by the background of the picture, which shows the brick texture decreasing in size and parallel lines converging, both perceived by the brain as indication of distance or depth.

If the humanoid creatures were of the same size, we would expect the pursuer to appear smaller in the distance. Since he appears bigger, we assume that he is much larger than the escapee.

1 texture

1 parallel lines

1 distant objects appear smaller