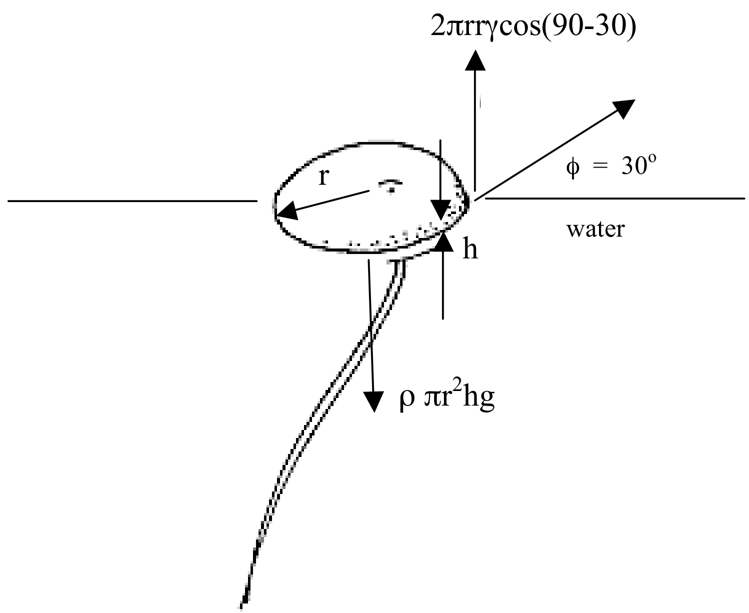
Answers 08

Question 1 (10 marks) 1

(a) The density of the tissue is greater than that of water, so the buoyancy force will not make it float, must rely on surface tension. Neglect the thin root in the calculations. 1

2



2

The upward component of surface tension force must balance the weight of the plant:

$$\rho\pi r^2 hg = 2\pi r\gamma\cos(90-\phi)$$

1

$$r = \frac{2\gamma\cos 60^o}{\rho hg} = \frac{2\times 73\times 10^{-3}\times 0.5}{1.1\times 10^3\times 1.0\times 10^{-3}\times 9.8} = 6.77\times 10^{-3}\text{m} \approx 7\text{ mm}$$

This is an upper limit, which seems like a reasonable answer as *lemma* has r < 7mm :

However, *lemna* tissue seems to contain a lot of air, so the tissue is less dense than water in reality. Larger floating leaves such as water lilies, contain air bladders to make the tissue less dense.

(b) (i) forces between water molecules (cohesion) are greater than forces between water molecules and the solid (adhesion), the contact angle is greater than 90° and water does not wet the solid, which is called hydrophobic, e.g. wax 1

(ii) Cohesion is smaller than adhesion, contact angle is less than 90°, the solid is called hydrophilic, e.g. clean glass. 1

1 examples

Question 2

(a) The vesicles with smaller radii (r) can withstand greater pressure: the Young-Laplace equation!

$$\Delta P = \frac{2\gamma}{r}$$ 1

Thus plotting differential pressure vs. 1/r will yield 2γ as a slope. 1

To get the appropriate units we can convert osmolality to pressure in Pa:
1 mosmol/lg = 1 mol/m^3

The approximate slope:

$$\frac{\Delta P}{\Delta\left(\frac{1}{r}\right)} \approx \frac{(1000-200)\times 8.314\times 300}{(29-5)\times 10^6} = \frac{1.99}{24} = 84\times 10^{-3}\text{Pa.m}$$ 2

slope = 2γ

$\gamma = 42 \times 10^{-3}$ N/m is the maximum membrane tension before vesicle breaks. 2

(b) Poiseuille's equation

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

2

Q volume flow of liquid with viscosity η through a pipe of length ℓ and radius r with a pressure difference ΔP.

Flow into branching smaller arteries

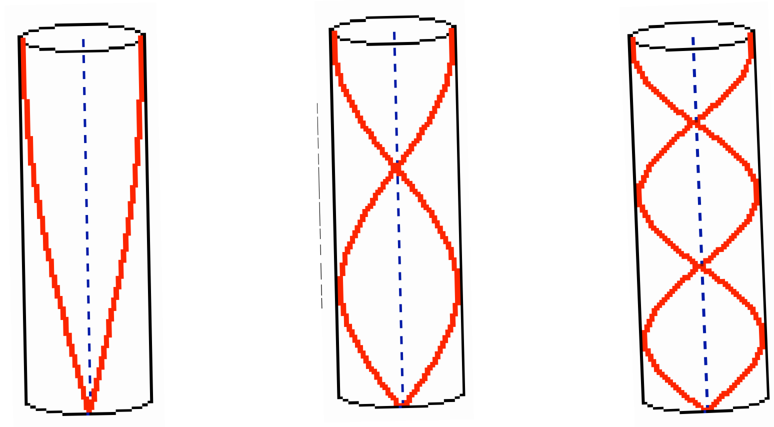
$$Q_L = 2Q_s$$ 1

$$\frac{\pi\Delta P_L r_L{}^4}{8\eta\ell_L} = 2\frac{\pi\Delta P_S r_S{}^4}{8\eta\ell_S}$$

$$\frac{\Delta P_S}{\ell_S} = \frac{1}{2}\frac{r_L{}^4}{r_S{}^4}\frac{\Delta P_L}{\ell_L} = 2.53\frac{\Delta P_L}{\ell_L}$$ 1

Thus a small change in radius is amplified

Question 3

(a) 

2

First three resonances, where length L = 0.17 m

$$f = \frac{v}{\lambda}$$

$$\lambda_1 = 4L$$ 1

$$\lambda_3 = \frac{4}{3}L$$

$$\lambda_5 = \frac{4}{5}L$$ 1

For v = 344 m/s, f_1 = 500 Hz, f_3 = 1500 Hz, f_5 = 2500 Hz

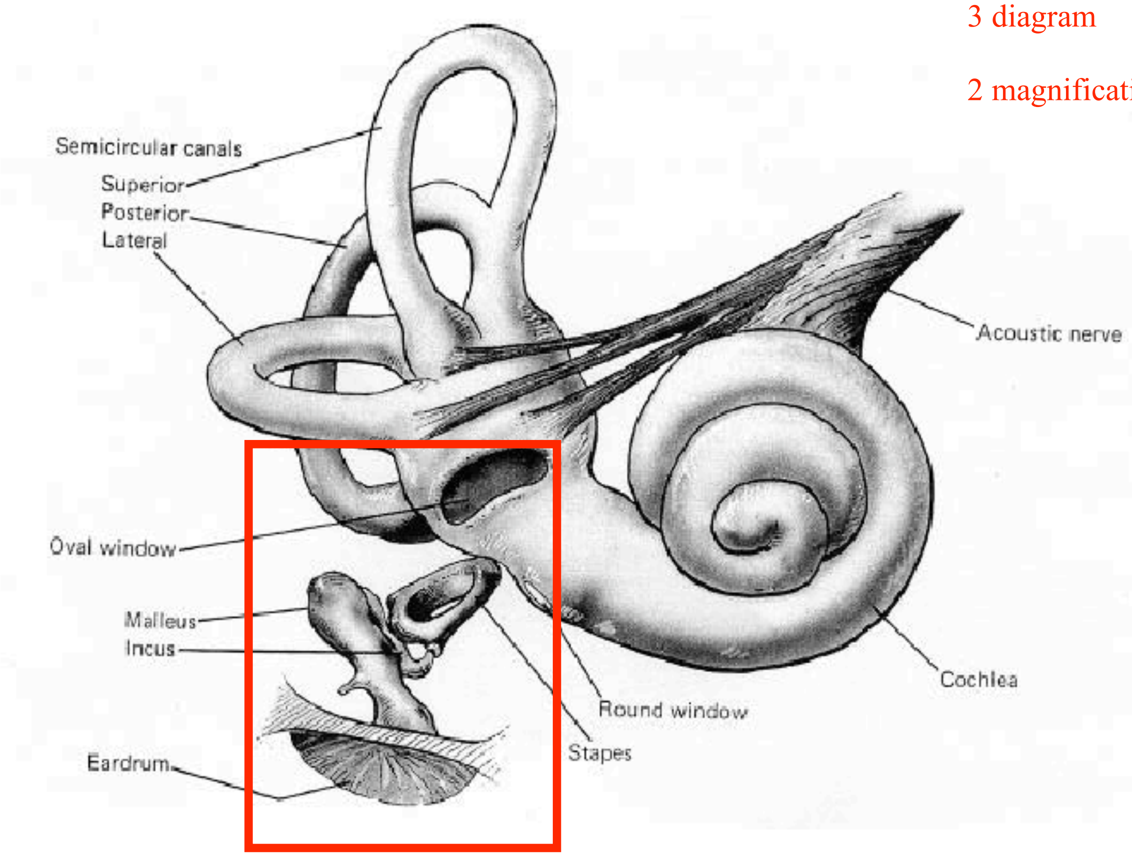
These resonant frequencies are called formants and appear often in speech sounds.
The human ear is most sensitive at frequencies near 3 kHz. 1

(b) The middle ear:

The middle ear is delimited by the eardrum and the oval window on the cochlea. There are three bones: malleus, incus and stapes. These act as a lever giving mechanical advantage of about 3 times. Further magnification of the signal comes from the ratio of the areas of the eardrum and the oval window (Pascal's principle) of about 20. At 3 kHz the magnification of the signal due to resonance in the ear canal is about 2. So, total magnification is 100 - 120 x.

3 diagram

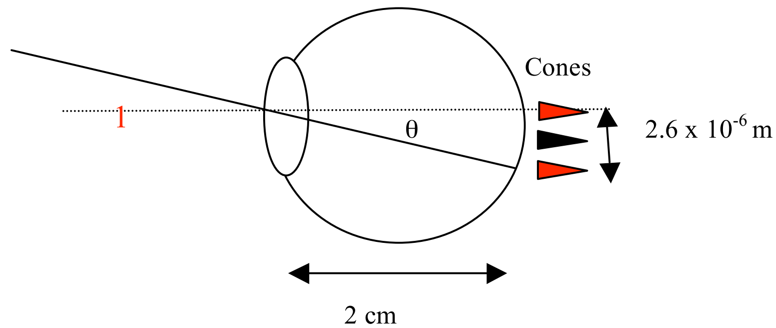
2 magnification



Question 4

1

(a) To distinguish two objects on the retina, at least one unexcited cone must intervene between two excited cones:



$$\tan\theta \approx \theta = \frac{2.6\mathrm{x}10^{-6}}{2\mathrm{x}10^{-2}} = 1.3\mathrm{x}10^{-4}\,\mathrm{rad}$$

(small angle approximation)

From the Rayleigh criterion the diffraction limit for resolution for 9.2 mm diameter pupil and 500 nm wavelength: 1

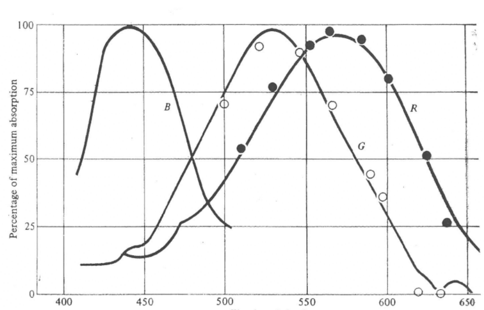
$$\sin\theta \approx \theta = 1.22\frac{\lambda}{d} = 1.22\frac{500\mathrm{x}10^{-9}}{9.2\mathrm{x}10^{-3}} = 0.64\mathrm{x}10^{-4}\,\mathrm{rad}$$ 1

It is not diffraction limited for fully open pupil. However, the eagle hunts in bright daylight, when the pupil is likely to be rather smaller than this. So, it is very close and there would be no point having greater cone density. 2

(b) (i) Points V and G are saturated spectral colours, V is blue violet of wavelength 470 nm, G is green with wavelength of 530 nm, C is white light, mixture of at least three colours.

(ii) The fovea of the normal human eye retina contains three types of cones, which are excited by light in different wavelength ranges as illustrated below. The V flash is near the limit of human vision and will excite some blue-sensitive and some green-sensitive cones. The G flash will excite mainly green-sensitive cones and some red-sensitive cones. The C flash will excite all three populations of cones. 2

The response curves for the cones in human eye:



(c) Distance Perception cues:

2

Texture gradients: objects close to us appear to have clearer texture gradients than objects far away eg ripples on water are clear close to us but not when far away; bricks on a building are distinguishable close to us but not far away
Order Sizes: the brain has learnt to know how large some objects should be eg the size of a man is smaller than a gum-tree. We also know that people don't change sizes as they walk away
Objects further away seem to be higher up in our vision image eg the sky is usually at the 'top' of our field of view and the ground is at the 'bottom' and therefore closer to us.
Radiating lines parallel lines that appear to merge indicate that the item is far away (railway lines etc)
Convergence: the physical turning in of both of our eyes as objects come closer to our eyes (6m or less). The more the eyes turn, the closer the object.
Shape Constancy We know that shape doesn't change even thought the image is different on our retina's eg a door does not change its shape whether we look at it closed or open.