MB&B 562: Exercise 6

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Question 1

1) (i) Given, $r = 5 \times 10^{-6}$ m

$$V = \frac{4}{3}\pi r^3$$

$$= \frac{4}{3}\pi (125)(10^{-18})$$

$$K = 10^{-3} \text{ N/m}$$

$$h = 10 \times 10^{-6} \text{ m}$$

Mass, $m = V \cdot \rho$

assuming density and viscocity of water,

$\rho = 10^3 \text{ kg/m}^3$

$\eta = 10^{-3}$ Pa.s

Hence, $$\frac{4km}{\gamma^2} = \frac{4(10^{-3})\frac{4}{3}\pi r^3 (10^3)}{(36)\pi^2 \eta^2 r^2}$$

$$= \frac{(16/3)(5 \times 10^{-6})}{(36)\pi(10^{-6})}$$

$$= \boxed{0.236}$$

(ii) The value of 0.236 indicates that hair bundle oscillations will be overdamped. When displaced, it will come back to its resting position very quickly.

Question 2

2) Reynold's Number is given by,

$$Re = \frac{\rho V L}{\eta}$$

Now, angular velocity $(\omega) = 2\pi f$

$$= 2\pi(10^3)$$

Hence, velocity, $V = \omega \cdot (\text{amplitude})$

$$= 2\pi(10^3)(50 \times 10^{-9})$$

$$= 3.14 \times 10^{-4} \text{ m/s}$$

So, $$Re = \frac{(10^3)(3.14 \times 10^{-4})(5 \times 10^{-6})}{(10^{-3})}$$

$$= \boxed{1.57 \times 10^{-3}}$$

(ii) Since Re is of the order of 10^{-3}, viscous forces dominate the inertial forces. Hence, the effects of inertial forces on the hair cells can be ignored.

Question 3

3) The ear can passively stimulate (and hence, detect) high levels (>40dB sensitivity). At lower intensities, that the ear can still sense, an active process would be required to enhance the vibrations for detection. This process is called the cochlear amplifier (CA) and works with the help of outer hair cells.