Civil 406 - 2014

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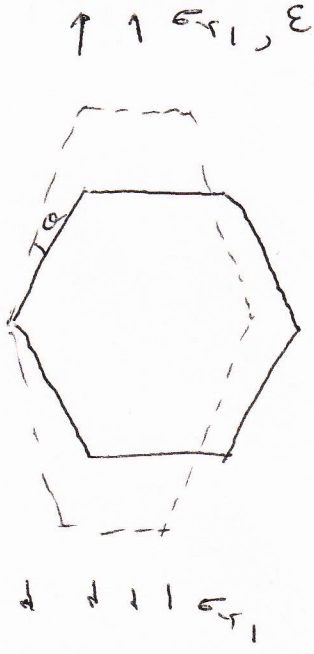
1 (a) Honeycomb : $\dfrac{3 t_1 \ell_1}{2\left[\frac{1}{2}\sqrt{3}\ell_1 \dfrac{\ell_1}{2}\right] + \sqrt{3}\ell_1^2} = \dfrac{2t_1}{\sqrt{3}\ell_1} = \bar{\rho}_1$

Triangular : $\dfrac{3 t_2 \ell_2}{\frac{\sqrt{3}}{2}\ell_2^2} = \dfrac{2\sqrt{3}\, t_2}{\ell_2} = \bar{\rho}_2$

(b)



$\sigma_{f1}\, \varepsilon \cdot \frac{3}{2}\sqrt{3}\ell_1^2 = \dfrac{M_p}{2}(4\theta \times 2)$

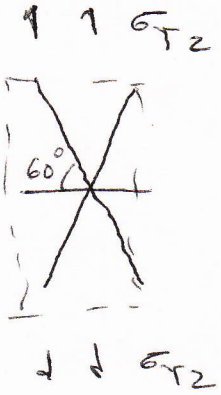
$M_p = \dfrac{\sigma_{fs} t_1^2}{4}$

$\varepsilon = \dfrac{\ell\theta \sin 30^\circ}{\ell \sin 60^\circ} = \dfrac{\theta}{\sqrt{3}}$

$\sigma_{f1} \dfrac{\theta}{\sqrt{3}} \dfrac{3\sqrt{3}\ell_1^2}{2} = \dfrac{\sigma_{fs} t_1^2}{4} 4\theta$

$\sigma_{f1} = \sigma_{fs} \dfrac{2}{3}\left(\dfrac{t_1}{\ell_1}\right)^2 = \dfrac{\bar{\rho}_1^2}{2}\sigma_{fs}$

(c)



$$\sigma_F \, t_2 \, \frac{\sqrt{3}}{2} \times 2 = \sigma_{T2} \, l_2$$

$$\sigma_{T2} = \sqrt{3}\left(\frac{t_2}{l_2}\right)\sigma_f$$

$$= \frac{\bar{\rho}_2}{2}\,\sigma_f$$

(d) $$\sigma_{TS} = \sigma_f \frac{\bar{\rho}_2}{2}$$

$$\sigma_{T1} = \frac{\bar{\rho}_1^{\,2}\,\bar{\rho}_2}{4}\,\sigma_f$$

2

(a)

$$-v\frac{dn}{dx} = (1-n)f(n) - ng(n)$$

$$v = 0$$

$$(1-n)f = ng$$

$$n = \frac{f}{f+g}$$

(b) For shooting ~~n=0~~ $x > h$ as no cross-bridges are dragged there & ~~f~~ $f = 0$

for $x > h$

$0 < x < h$

$$-v\frac{dn}{dx} = (1-n)f_0 - ng_0$$

$$n = \underbrace{A \exp\left[\frac{(f_0+g_0)x}{v}\right]}_{\text{homogeneous}} + \underbrace{\frac{f_0}{f_0+g_0}}_{\text{particular}}$$

$$n(h) = 0$$

$$\Rightarrow A = \frac{-f_0}{(f_0+g_0)\exp\left[\frac{(f_0+g_0)h}{v}\right]}$$

$$n(x) = \frac{f_0}{f_0+g_0}\left[1 - \exp\left[\frac{(f_0+g_0)}{v}(x-h)\right]\right]$$

ie $$n(0) = \frac{f_0}{f_0+g_0}\left[1 - \exp\left\{-\frac{(f_0+g_0)h}{v}\right\}\right]$$

$x < 0$

$$-v\frac{dn}{dx} = -ng_1$$

$$n = c\exp\left(\frac{g_1 x}{v}\right)$$

$$n(0) = c = \frac{f_0}{f_0+g_0}\left[1 - \exp\left\{\frac{-(f_0+g_0)h}{v}\right\}\right]$$

$$n(x) = \frac{f_0}{f_0+g_0}\left[1-\exp\left\{\frac{-(f_0+g_0)h}{v}\right\}\right]\exp\left(\frac{g_1 x}{v}\right)$$

(c)

It would involve writing a PDE for $n(x,t)$ of the form

$$\frac{\partial n}{\partial t} = -v\frac{\partial n}{\partial x} = (1-n)f - ng$$

and solving subject to $\frac{\partial T_1}{\partial t} = 0$.

3(a)

(i) Persistence length is a material property dependent on bending stiffness D & thermal activation kT

$$\zeta_p = \frac{D}{kT}$$

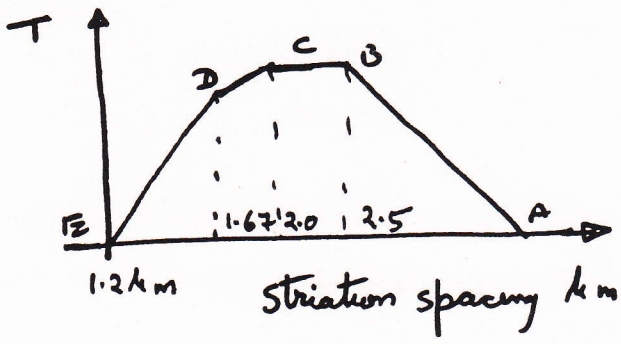
Over a length ζ_p angular correlation is lost & the filament can be thought to be rubber-like. Thus if filament length $l \gg \zeta_p$ then modulus is entropic & if $l \ll \zeta_p$ then fibre behaves like a stiff beam.

(ii) If nodal connectivity is high (eg. triangulated in 2D) then modulus of structure is governed by stretching stiffness of filaments but if connectivity is low (honeycombs in 2D) modulus is governed by bending stiffness of filaments

3 (b) With a high Ca^{2+} concentration in the sarcoplasm, the myosin head is tightly bound to an adjacent actin filament. Before long ATP binds to the myosin & a conformational change reduces the affinity of myosin to actin & the two seperate, simultaneously causing the myosin to shift a distance of 5nm towards the +ve end of the actin filament, where it rebinds at a new location. Hydrolysis then causes the release of P_i from the ATP to produce ADP & the associated conformational change triggers the power stroke that drives the actin filament in the direction of the -ve end. During the power stroke the ADP is released returning the myosin to its original state, ready for the next ATP to come along & bond.

(25%)

(c)



The tension changes with change in overlap between the thick & thin filaments. Between B & C the overlap is a constant & so is the tension.

4(a)

The cytoskeleton is the internal soft skeleton of the cells. The microtubules are stiff & hollow tubes made from tubulin. They emanate from the centrosome & small molecular motors carry proteins along them. They also aid cell division.

The actin cortex form a 2D network providing support for the membrane & allowing transport of protein cargo.

The intermediate filaments are passive rope-like filaments ~~are~~ made from keratin. The anchor to cell junctions & link adjacent cells.

(b)

(i)

The Na^+/K^+ has 3 high affinity Na^+ binding sites in the E1 configuration & 2 low affinity K^+ sites

4 b

(i) In its E1 conformation, the Na^+/K^+ ATPase has three high-affinity Na-binding sites and two low-affinity K- binding sites accessible to the cytosolic surface of the protein. The K_m for binding of Na^+ to these cytosolic sites is 0.6 mM, a value considerably lower than the intracellular Na concentration of ≈ 12 mM; as a result, Na^+ ions normally will fully occupy these sites. Conversely, the affinity of the cytosolic K-binding sites is low enough that K^+ ions, transported inward through the protein, dissociate from E1 into the cytosol despite the high intracellular K concentration. During the E1→E2 transition, the three bound Na^+ ions become accessible to the exoplasmic face, and simulta- neously the affinity of the three Na-binding sites becomes reduced. The three Na^+ ions, transported outward through the protein and now bound to the low-affinity Na^+ sites exposed to the exoplasmic face, dissociate one at a time into the extracellular medium despite the high extracellular Na concentration. Transition to the E2 conformation also generates two high-affinity K^+ sites accessible to the exoplasmic face. Because the K_m for K^+ binding to these sites (0.2 mM) is lower than the extracellular K^+ concentration (4 mM), these sites will fill with K^+ ions. Similarly, during the E2→E1 transition, the two bound K^+ ions are transported inward and then released into the cytosol.

(iii) Ouabin binds to the exoplasmic domain of the Na^+/K^+ ATPase & inhibits its activity. Thus, animal cells treated with Ouabin cannot maintain the K^+ & Na^+ ion gradients

(ii) Overall per ATP molecule hydrolysed the pump moves 3 Na^+ ions & 2 K^+ ions. Increasing the ATP concentration will allow more pump activity.