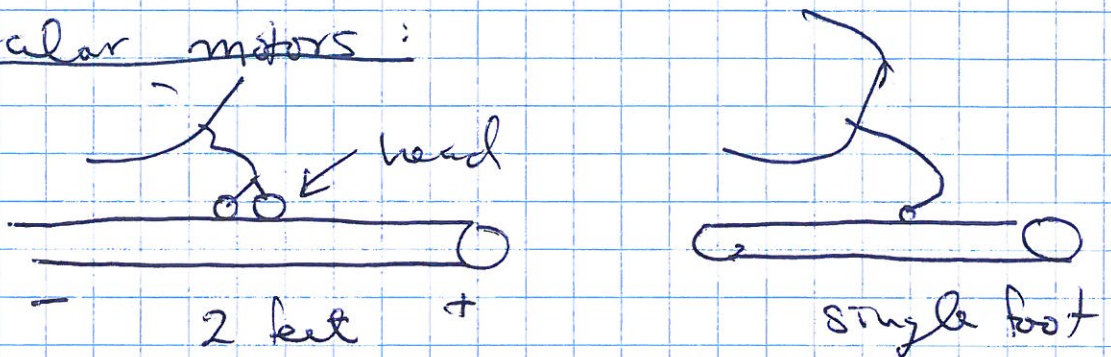
Thermal Ratchets (p. 306)

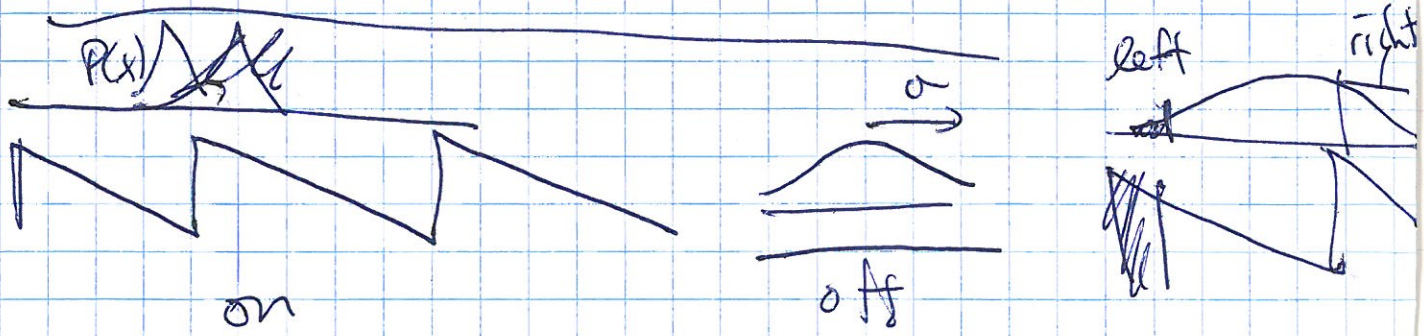
Molecular motors:



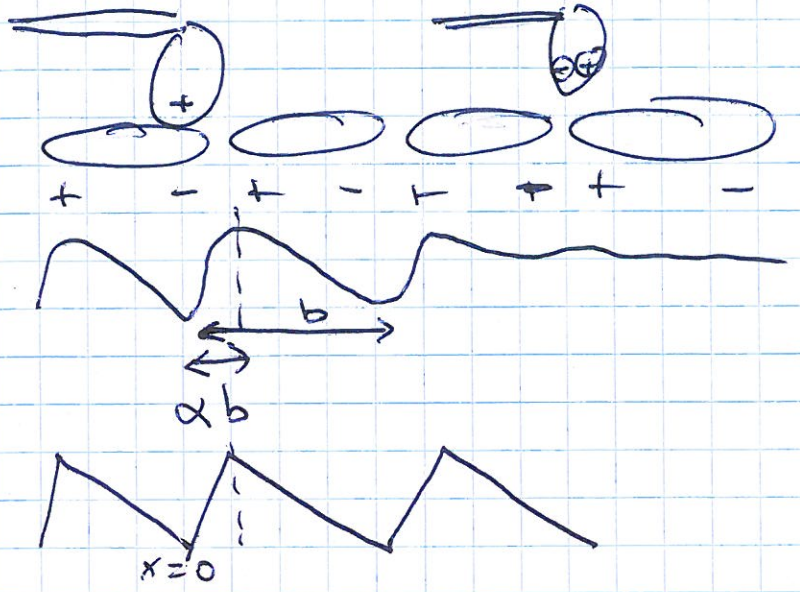
Actin ≡ myosin I = 1 foot & myosin II = 2 foot

microtubule ≡ kinesin = 2 heads
dynein = 2 heads

ATP → power stroke → ADP
(hydrolosis)



Why? charged head, ATP neutralizes charge



Approx: $P(x) = (1 - \frac{|x|}{w})/w$ instead of Gaussian

choose $w = \sqrt{6}\,\sigma \sim 2.5\sigma$ ($\sigma^2 = \langle x^2 \rangle = 2Dt$)

$\sigma \equiv$ ~~how~~

$$P_R = \int_{\alpha b}^{w} P(x)\,dx = \frac{1}{2}\left(1 - \frac{\alpha b}{w}\right)^2 \qquad (w > \alpha b)$$

$$P_L = \int_{-b+\alpha b}^{-w} P(x)\,dx \qquad \text{if } w < (1-\alpha)b \rightarrow P_L = 0$$

$$= \frac{1}{2}\left(1 - \left(b - \frac{\alpha b}{w}\right)\right)^2$$

$$P_{net} = P_R - P_L$$

$$= 0 \qquad 0 < w < \alpha b$$

$$= \frac{1}{2}(1 - \alpha b/w)^2 \qquad \alpha b < w < (1-\alpha)b$$

$$= \frac{b}{w}\left(1 - 2\frac{b}{w}\right)(1 - 2\alpha) \qquad (1-\alpha)b < w$$

Properties

for $\alpha = \frac{1}{2}$ $P_{net} = 0$

$\alpha = 0 \Rightarrow P_{net} = \frac{1}{2}$

- P_{max}? $\frac{\partial P_{net}}{\partial \omega} = 0 \rightarrow \omega_b = 1$ & P_{max}

$$P_{max} = \frac{1}{2}(1 - 2\alpha)$$

Estimate: $\omega = \sqrt{6\sigma} = (12Dt)^{1/2}$

For step: $b = 8$ & P_{max} @ $\omega = b = 8nm$

now $D \sim 10^{-12} - 10^{-14}\ m^2/s$

$$\rightarrow \underset{\text{switch}}{t} = \frac{(8nm)^2}{12(10^{-12})} \sim 5\times10^{-6} \text{ or } 5\times10^{-4}\ s$$

$\rightarrow$ rate $\sim 10^3 - 10^5$ steps/second

reality – myosin $\sim$ 200 steps/s