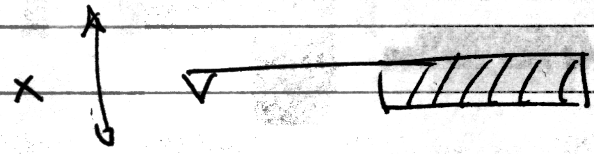
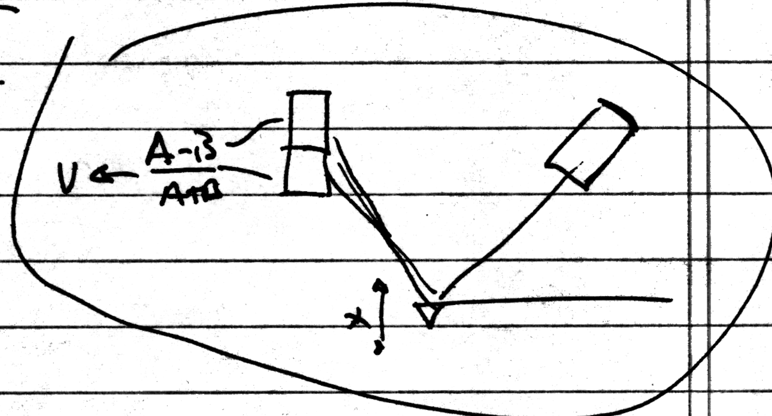
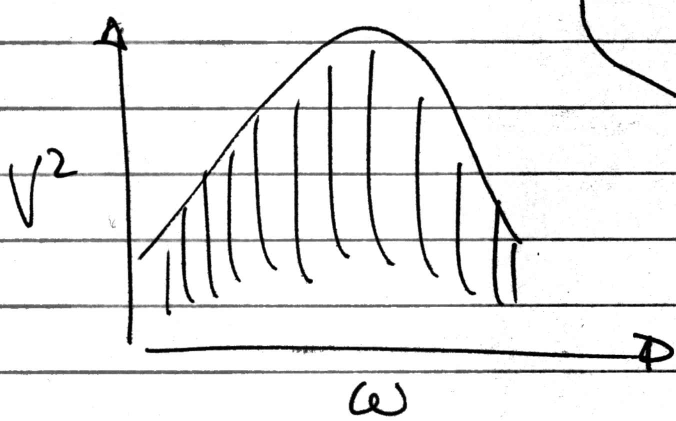
equipartition



$$\frac{1}{2} k_B T = \frac{1}{2} k_s x^2$$

$$k_s = \frac{k_B T}{x^2}$$

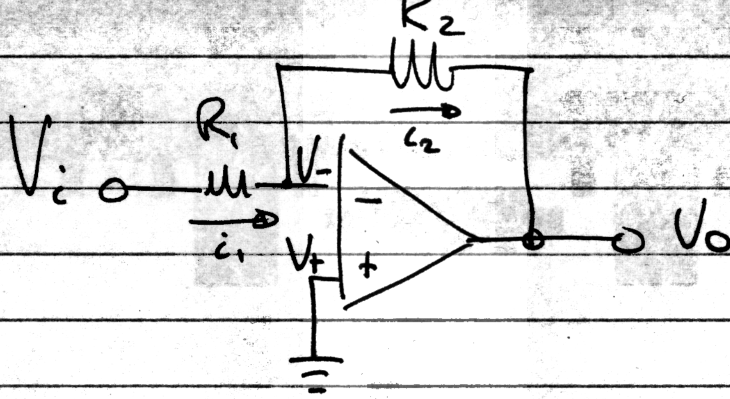




$$\boxed{\text{slope} = \frac{nm}{V}}$$

$$k_s = \frac{k_B T}{\left(\int x^2(\omega)\, d\omega\right)} = \frac{k_B T}{\int V^2 d\omega \cdot \text{slope}^2} \qquad \frac{pN\ nm}{nm^2}$$

$$DB = 20 \operatorname{Log} \frac{V^2}{(\text{Power})}$$



$$\boxed{V_o = a(V_+ - V_-)}$$

$$\frac{V_i - V_-}{R_1} = \frac{V_- - V_o}{R_2}$$

$$\frac{V_i}{R_1} - \frac{V_-}{R_1} = \frac{V_-}{R_2} - \frac{V_o}{R_2}$$

$$\frac{V_i}{R_1} + \frac{V_o}{R_2} = V_-\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = V_-\left(\frac{R_1+R_2}{R_1 R_2}\right)$$

$$\therefore \quad V_- = V_i \frac{R_2}{(R_1+R_2)} + V_o \frac{R_1}{(R_1+R_2)}$$

$$\boxed{V_o = -aV_-}$$

$$V_o = -V_i \frac{aR_2}{(R_1+R_2)} - V_o \frac{aR_1}{(R_1+R_2)}$$

$$V_o\left(1 + \frac{aR_1}{R_1+R_2}\right) = -V_i \frac{aR_2}{(R_1+R_2)}$$

$$\therefore \quad V_0 = \frac{-V_i\left(\frac{aR_2}{R_1+R_2}\right)}{\left(1+\frac{aR_1}{R_1+R_2}\right)} \qquad a \gg 1$$

$$\boxed{V_0 = -V_i\left(\frac{R_2}{R_1}\right)} \quad ✓$$

Golden rules

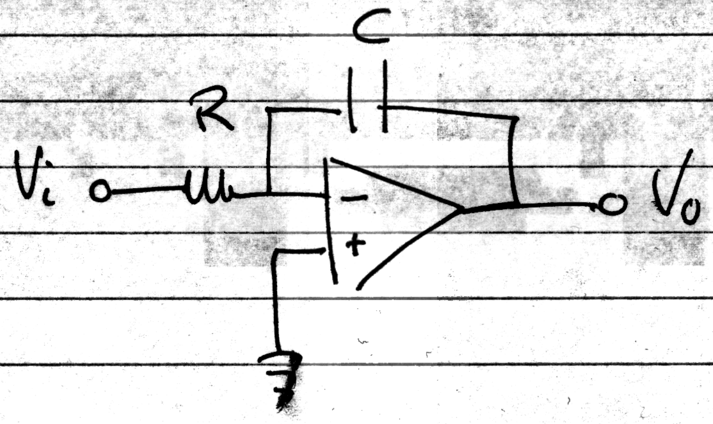
no input current.

$\boxed{V_+ = V_-}$! Amp will do whatever to make $\boxed{V_+ = V_-}$

same.

$$\frac{V_i - V_-}{R_1} = \frac{V_- - V_0}{R_2} \qquad V_- = V_+ = 0$$

$$\frac{V_i}{R_1} = \frac{-V_0}{R_2} \Rightarrow \boxed{V_0 = -V_i\frac{R_2}{R_1}}$$



integrator

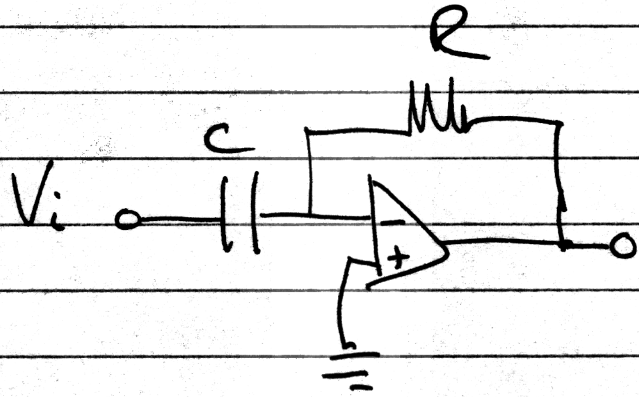
$$\boxed{\frac{V_i}{R} = -C\frac{dV_o}{dt}}$$

$$C = \frac{Q}{V} \Rightarrow Q = CV$$

$$\frac{dQ}{dt} = i = C\frac{dV}{dt}$$

$$\Downarrow$$

$$-\frac{1}{RC}\int V_i dt = V_o$$



differentiator

$$C\frac{dV_i}{dt} = -\frac{V_o}{R} \Rightarrow \boxed{V_o = -RC\frac{dV_i}{dt}}$$