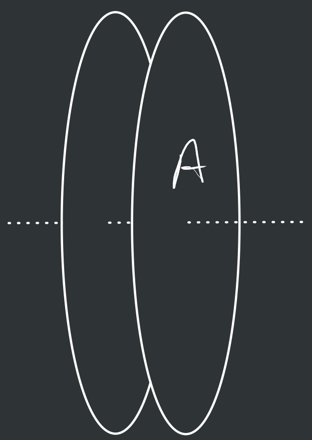
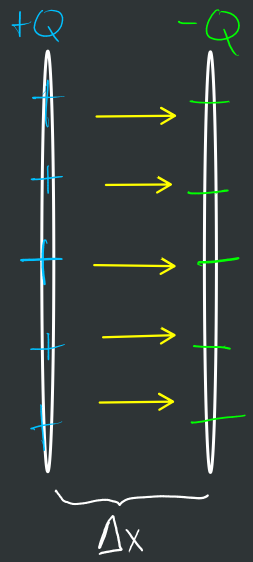
After this you can

- use the new quantity of capacitance to relate the charge stored on a capacitor to the voltage between the plates
- use the physical properites of a capacitor to predict how much charge can be stored
- discuss energy storage in a capacitor




$$\Delta V = E \cdot \Delta x$$

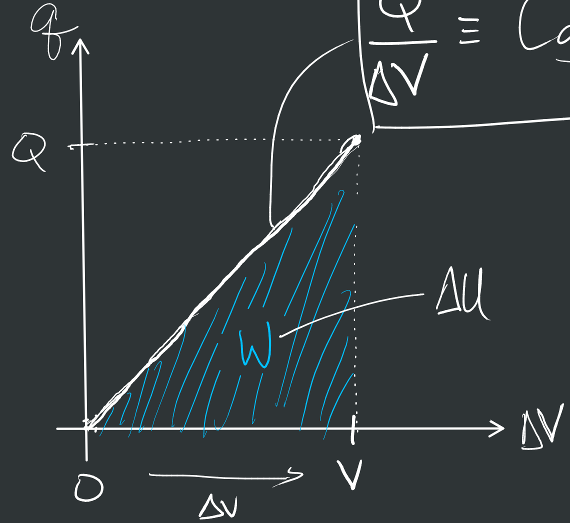
$$\Delta x \cdot E = \frac{Q}{\epsilon_0 A} \cdot \Delta x$$

$$\Delta V = \frac{Q}{\epsilon_0 A} \cdot \Delta x$$

$$\frac{\epsilon_0 A}{\Delta x} = \frac{Q}{\Delta V} = C$$

parallel plate capacitor

$$C = \frac{\epsilon_0 A}{\Delta x}$$




$$\frac{Q}{\Delta V} \equiv \text{Capacitance}$$

Units

$$= \frac{[\text{Coulomb}]}{[\text{Volt}]} = \left[\frac{C \cdot C}{J}\right] = [\text{Farad}]$$

$\mu F \rightarrow 10^{-6}\,F$

$nF \rightarrow 10^{-9}\,F$

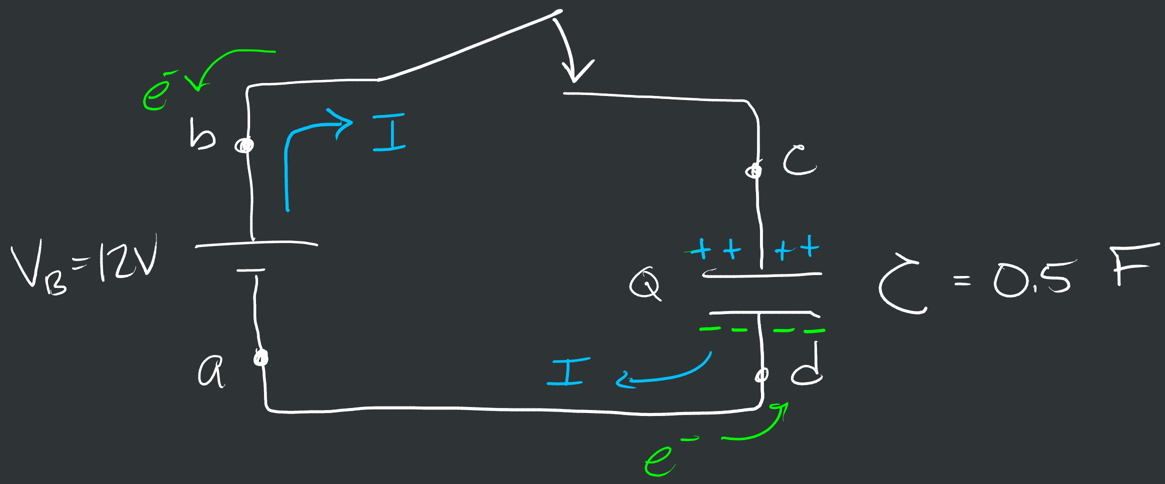
$pF \rightarrow 10^{-12}\,F$

$$\boxed{\Delta U = \frac{1}{2} \Delta V \, Q}$$

$$C = \frac{Q}{\Delta V}$$

energy stored in a capacitor

After this you can
- determine the charge stored on a capacitor due to a potential
- determine the equivalent capacitance due to multiple capacitors connected together




$\Delta V_B = \Delta V_c$ ~ then I stops and Q is complete

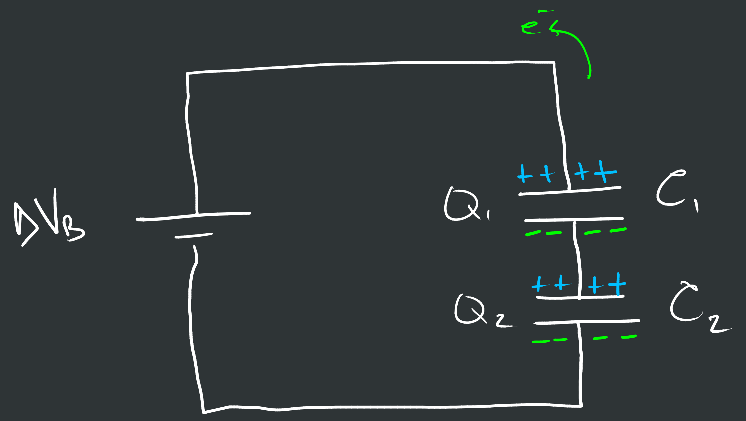
$$\Delta V_B - \Delta V_c = 0$$

$$\Delta V_B = \Delta V_c$$

$$\frac{Q}{\Delta V_c} = C$$

$$\Delta V_c = \frac{Q}{C}$$

$$\Delta V_B = \frac{Q}{C}$$




$$Q_1 = Q_2 = Q$$

$$\Delta V_B - \Delta V_1 - \Delta V_2 = 0$$

$$\Delta V_B = \Delta V_1 + \Delta V_2$$

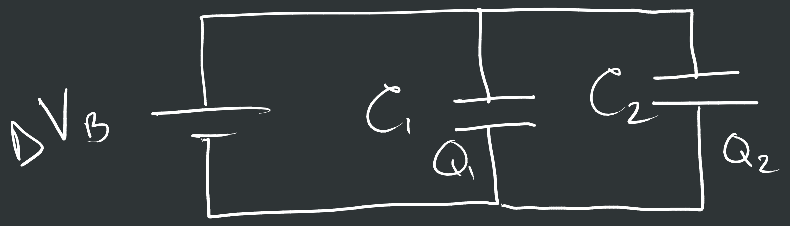
$$\Delta V_B = \frac{Q_1}{C_1} + \frac{Q_2}{C_2}$$

$$\downarrow$$

$$\Delta V_B = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\Delta V_B = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

$$\boxed{\Delta V_B = \frac{Q}{C_E}} \quad \text{—} \quad \underbrace{\boxed{C_E = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots}}}_{\text{Capacitors in series}}$$




$$\Delta V_B - \Delta V_1 = 0$$

$$\Delta V_B = \frac{Q_1}{C_1}$$

$$Q_1 = \Delta V_B \cdot C_1$$

$$\Delta V_B - \Delta V_2 = 0$$

$$\Delta V_B = \frac{Q_2}{C_2}$$

$$Q_{total} = Q_1 + Q_2 + \ldots$$

$$\Delta V_B = \frac{Q_{total}}{C_E}$$

$$Q_{total} = \Delta V_B \cdot C_1 + \Delta V_B \cdot C_2 + \ldots$$

$$Q_{total} = \Delta V_B \left( C_1 + C_2 + \ldots \right)$$

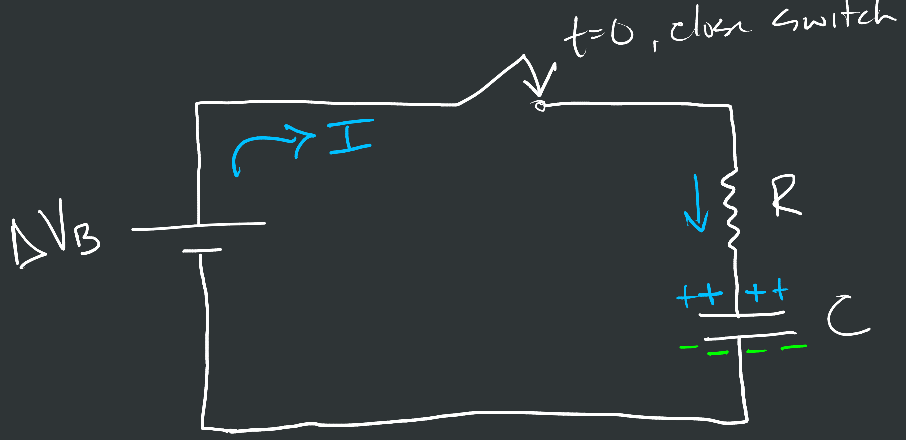
$$\Delta V_B = \frac{Q_{total}}{C_1 + C_2 + \ldots}$$

$$\boxed{C_E = C_1 + C_2 + \ldots}$$

capacitors in parallel

After this you can

- describe the exponential behavior of RC circuits
- use the relationships for current or charge to solve for an unknown quantity




$$\Delta V_B - \Delta V_R - \Delta V_C = 0$$

$$\Delta V_B = \Delta V_R + \Delta V_C$$

$$\Delta V_R = I(t) \cdot R \qquad \Delta V_C = \frac{Q(t)}{C}$$

$\underline{t=0}$

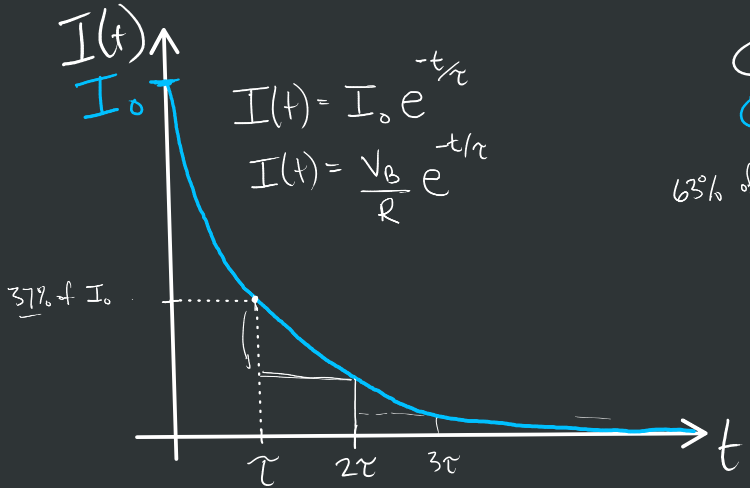
$$\Delta V_C = 0$$

$$\Delta V_R = \Delta V_B = I_0 \cdot R$$

$\underline{t = \text{long time}}$

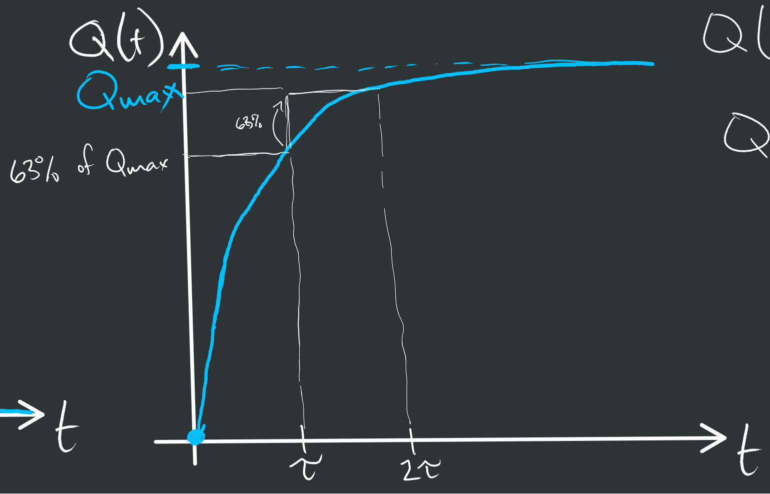
$$\Delta V_C = \Delta V_B \Rightarrow Q_{max} = V_B \cdot C$$

$$\Delta V_R = 0$$




$$I(t) = I_0 e^{-t/\tau}$$

$$I(t) = \frac{V_B}{R} e^{-t/\tau}$$




$$Q(t) = Q_{max}\left(1 - e^{-t/\tau}\right)$$

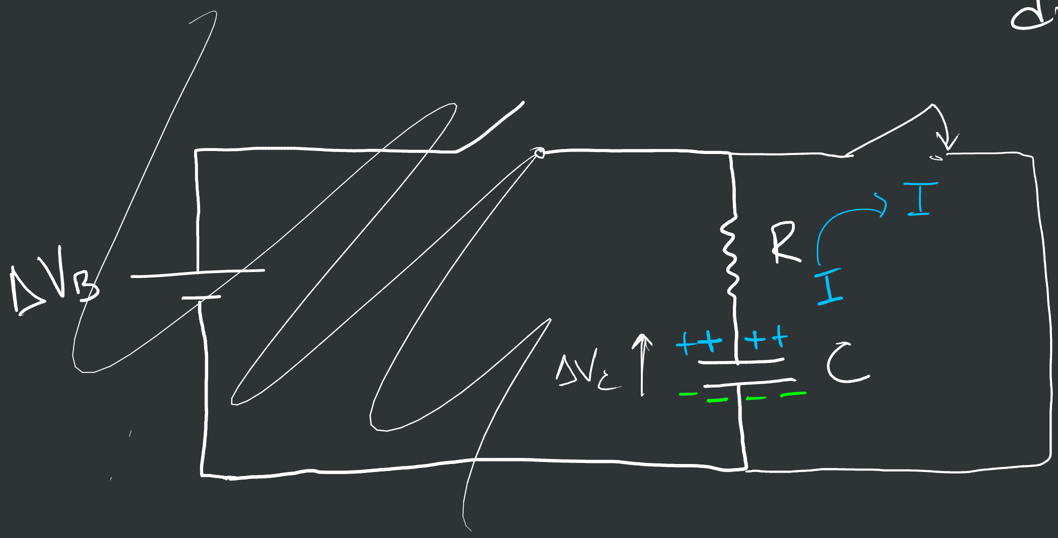
$$Q(t) = V_B \cdot C\left(1 - e^{-t/\tau}\right)$$

$$\tau = R \cdot C$$

seconds

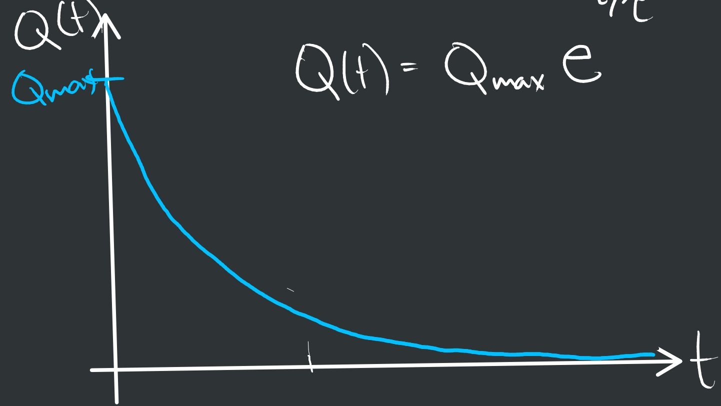
charging a capacitor

discharging a capacitor

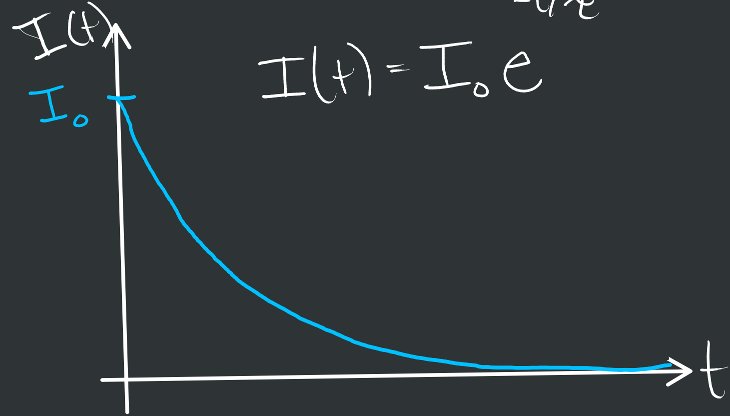



$$\Delta V_C - \Delta V_R = 0$$

$$\Delta V_C = \Delta V_R$$




$$Q(t) = Q_{max}\, e^{-t/\tau}$$




$$I(t) = I_0\, e^{-t/\tau}$$