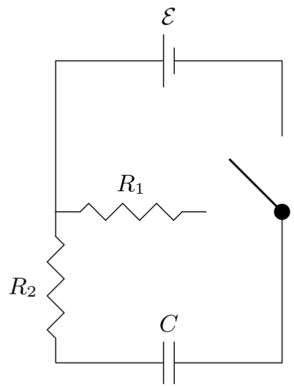
Charge/Discharge

The circuit below has a switch that can be flipped to be either horizontal or vertical. The capacitor starts discharged, but can be charged or discharged again by flipping the switch appropriately.



(a) Select all that are true.

- ☐ When the switch is horizontal the capacitor is discharging
- ☐ When the switch is horizontal the capacitor is charging
- ☐ The time constant for charging is R_2C
- ☐ The time constant for discharging is R_1C
- ☐ The maximum possible current on any wire is $\mathcal{E}/R_2$
- ☐ The minimum possible current on any wire is $\mathcal{E}/(R_1+R_2)$
- ☐ The capacitor can end up with positive charges on its left side

(b) The capacitor is initially discharged. The switch is put into the horizontal position for a time $4\ln(2)(R_1+R_2)C$, and then into the vertical position for $2\ln(2)R_2C$. Which of the following is the magnitude of the voltage difference across the capacitor at that point?

○ $\mathcal{E}$ ○ $\mathcal{E}/2$ ○ $2\mathcal{E}$ ○ $\mathcal{E}/4$ ○ $4\mathcal{E}$ ○ $3\mathcal{E}/4$ ○ $4\mathcal{E}/3$

(c) Someone wants to make this circuit charge as quickly as possible and discharge as slowly as possible. Which of the following can accomplish what they want?

- ☐ Making R_1 very large and R_2 very small
- ☐ Making R_1 very small and R_2 very large
- ☐ Making R_1 very large and R_2 very large
- ☐ Making R_1 very small and R_2 very small
- ☐ Making $\mathcal{E}$ very large and C very small
- ☐ Making $\mathcal{E}$ very small and C very large
- ☐ Making $\mathcal{E}$ very large and C very large
- ☐ Making $\mathcal{E}$ very small and C very small

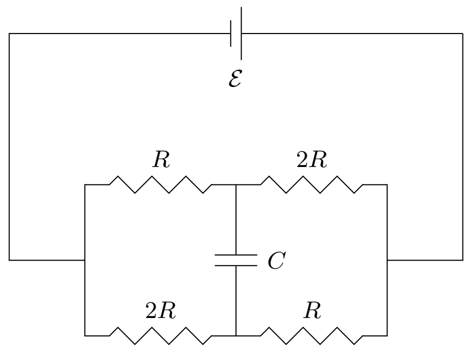
(d) Suppose $R_1 = R_2 = 1\ \text{k}\Omega$, $\mathcal{E} = 5$ V, and $C = 1$ mF. Suppose the capacitor starts discharged. The switch is put into the vertical position. What is the current going through the battery 1 second after the switch was made vertical? (Round to 4 decimal places.)

$I_{\text{bat,1s}} =$ ☐ A

General Circuits	**Equivalent Resistance**	**Exponential Decay**
$\Delta V_{\text{loop}} = 0,\ I_{\text{in}} = I_{\text{out}},\ \Delta V_{\text{battery}} = \mathcal{E}$ $\Delta V_{\text{resistor}} = -IR,\ \Delta V_{\text{capacitor}} = Q/C$ $P = \lvert I\Delta V\rvert = (\Delta V)^2/R = I^2R$	$R_{\text{series}} = R_1 + R_2 + \cdots$ $R_{\text{parallel}} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\cdots}$	$\frac{dy}{dt} = \lambda(y_{\text{eq}} - y)$ $\implies y = (y_0 - y_{\text{eq}})e^{-\lambda t} + y_{\text{eq}}$ $\tau = t_{1/e} = 1/\lambda = RC,\ t_{1/2} = \ln(2)t_{1/e}$

Strange capacitor

The capacitor in the circuit below starts discharged. After some time, it is fully charged.



(a) When the capacitor is discharged, what is the current through the battery?

○ $\frac{\mathcal{E}}{R}$ ○ $\frac{\mathcal{E}}{6R}$ ○ $\frac{3\mathcal{E}}{4R}$ ○ $\frac{\mathcal{E}}{3R}$ ○ $\frac{2\mathcal{E}}{3R}$ ○ $\frac{6\mathcal{E}}{R}$ ○ $\frac{4\mathcal{E}}{3R}$ ○ $\frac{3\mathcal{E}}{R}$

(b) When the capacitor is fully charged, what is the current through the battery?

○ $\frac{\mathcal{E}}{R}$ ○ $\frac{\mathcal{E}}{6R}$ ○ $\frac{3\mathcal{E}}{4R}$ ○ $\frac{\mathcal{E}}{3R}$ ○ $\frac{2\mathcal{E}}{3R}$ ○ $\frac{6\mathcal{E}}{R}$ ○ $\frac{4\mathcal{E}}{3R}$ ○ $\frac{3\mathcal{E}}{R}$

(c) Suppose $\mathcal{E} = 12$ V. What is the magnitude of the capacitor's final voltage, and which side is positively charged? (Round to 2 decimal places.)

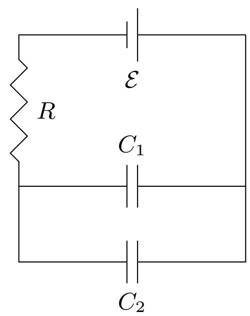
$|\Delta V_C| =$ ______ V

○ Top side ○ Bottom side ○ Cannot be determined

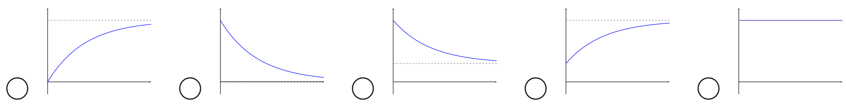
General Circuits	Equivalent Resistance	Exponential Decay
$\Delta V_{\text{loop}} = 0,\ I_{\text{in}} = I_{\text{out}},\ \Delta V_{\text{battery}} = \mathcal{E}$	$R_{\text{series}} = R_1 + R_2 + \cdots$	$\frac{dy}{dt} = \lambda(y_{\text{eq}} - y)$
$\Delta V_{\text{resistor}} = -IR,\ \Delta V_{\text{capacitor}} = Q/C$	$R_{\text{parallel}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots}$	$\implies y = (y_0 - y_{\text{eq}})e^{-\lambda t} + y_{\text{eq}}$
$P = \lvert I\Delta V\rvert = (\Delta V)^2/R = I^2R$		$\tau = t_{1/e} = 1/\lambda = RC,\ t_{1/2} = \ln(2)t_{1/e}$

Parallel capacitors

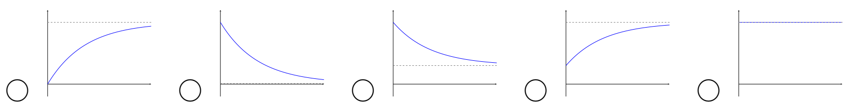
The two capacitors below are wired in parallel. They both start discharged. *(Your formula sheet intentionally does not have an 'equivalent capacitance' formula. Perhaps you should think of one...)*



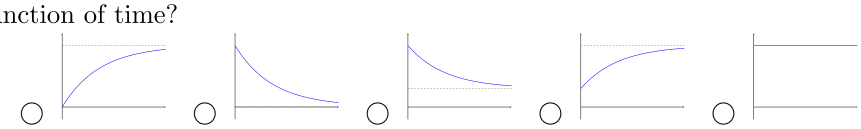
(a) Which of the following best depicts the magnitude of the voltage across the battery as a function of time?



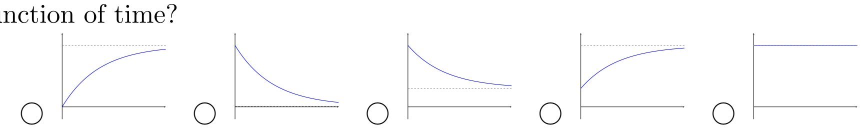
(b) Which of the following best depicts the magnitude of the current across the battery as a function of time?



(c) Which of the following best depicts the magnitude of the current across the resistor as a function of time?



(d) Which of the following best depicts the magnitude of the voltage across the resistor as a function of time?



(e) What is the sum of the equilibrium charges on the two capacitors? (Write the mathematical expression.)

$Q_{1,\text{equilibrium}} + Q_{2,\text{equilibrium}} =$ ☐

Use what you found to deduce the 'equivalent capacitance' of the capacitors in parallel, i.e. the capacitance of the single capacitor that could replace them that would otherwise behave identically,

$C_{\text{equivalent parallel}} =$ ☐

General Circuits	**Equivalent Resistance**	**Exponential Decay**
$\Delta V_{\text{loop}} = 0,\ I_{\text{in}} = I_{\text{out}},\ \Delta V_{\text{battery}} = \mathcal{E}$	$R_{\text{series}} = R_1 + R_2 + \cdots$	$\frac{dy}{dt} = \lambda(y_{\text{eq}} - y)$
$\Delta V_{\text{resistor}} = -IR,\ \Delta V_{\text{capacitor}} = Q/C$	$R_{\text{parallel}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots}$	$\implies y = (y_0 - y_{\text{eq}})e^{-\lambda t} + y_{\text{eq}}$
$P = \lvert I\Delta V \rvert = (\Delta V)^2/R = I^2 R$		$\tau = t_{1/e} = 1/\lambda = RC,\ t_{1/2} = \ln(2) t_{1/e}$