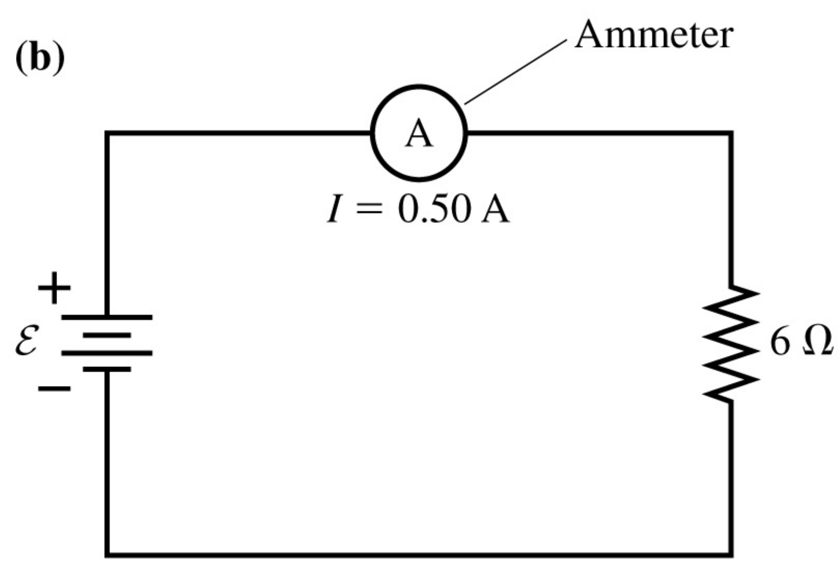
PHY294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Help-room hours: 12:40-2:40 Monday (note change); 3:00-4:00 PM Friday**
  - **No hand-in problem for tomorrow; for next Wed 31.79**
- Quizzes by iclicker (sometimes hand-written)
- Average on exam is around 65; will pass back tomorrow
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

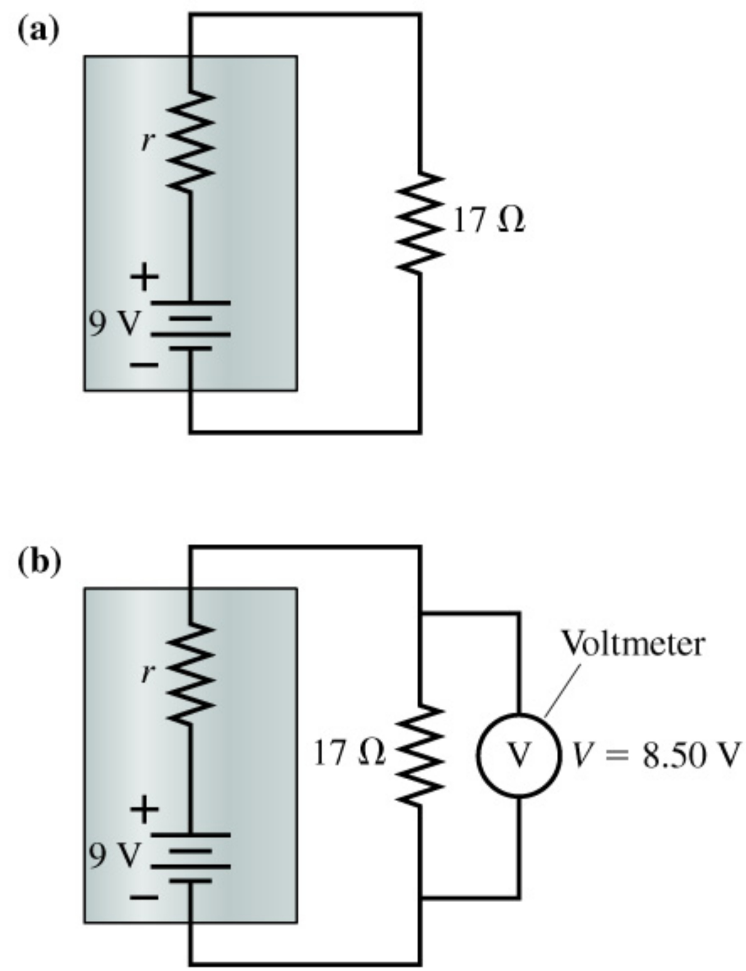
Ammeters

- An ammeter is a device that measures the current in a circuit
- It's stuck directly in the path of the current (i.e. in series) so you would like its resistance to be as small as possible so that it doesn't affect the circuit too much
    - an ideal ammeter would have zero resistance
- Nowadays ammeters are digital devices but old-fashioned ones use a galvanometer
    - how a galvanometer works depends on the interactions of currents and magnetic fields so we'll leave that for the next chapter



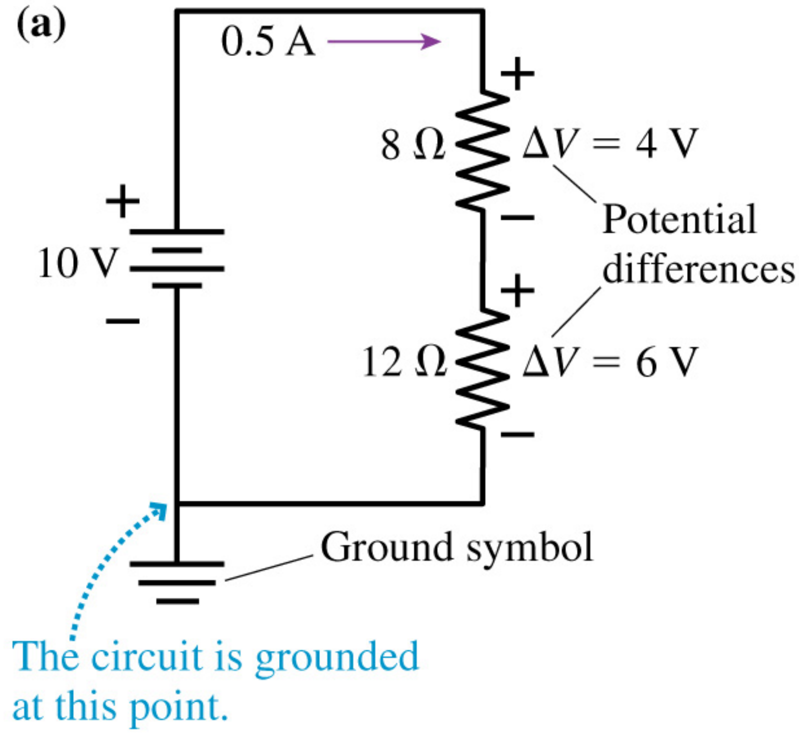
Voltmeters

- If I want to measure a voltage in a circuit, I use a voltmeter
- A voltmeter is placed in parallel in the circuit, so you would like its resistance to be as large as possible in order to affect the circuit as little as possible
  - an ideal voltmeter would have infinite resistance
- Modern voltmeters are digital but the old-fashioned ones used a galvanometer

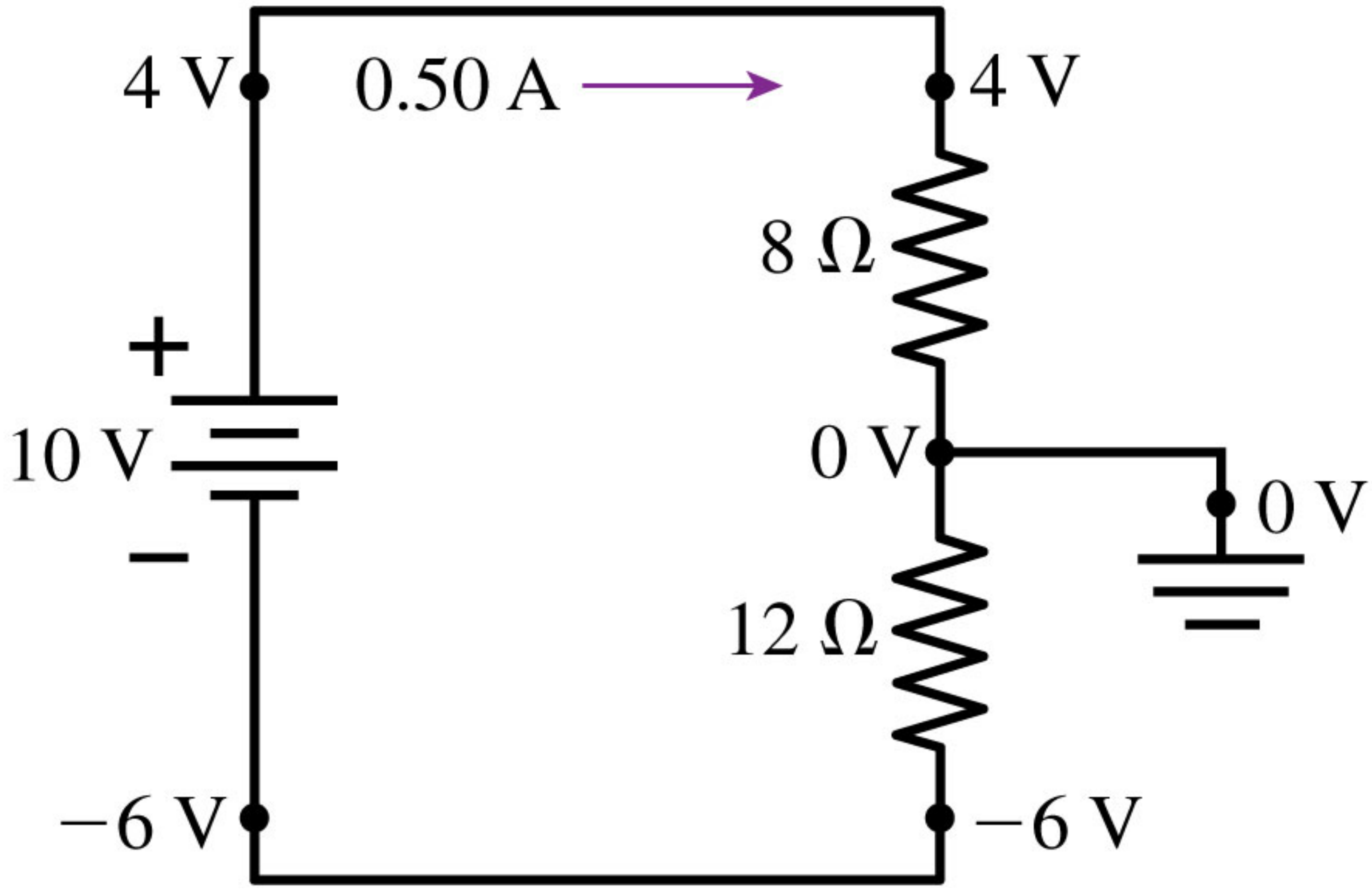


Grounded

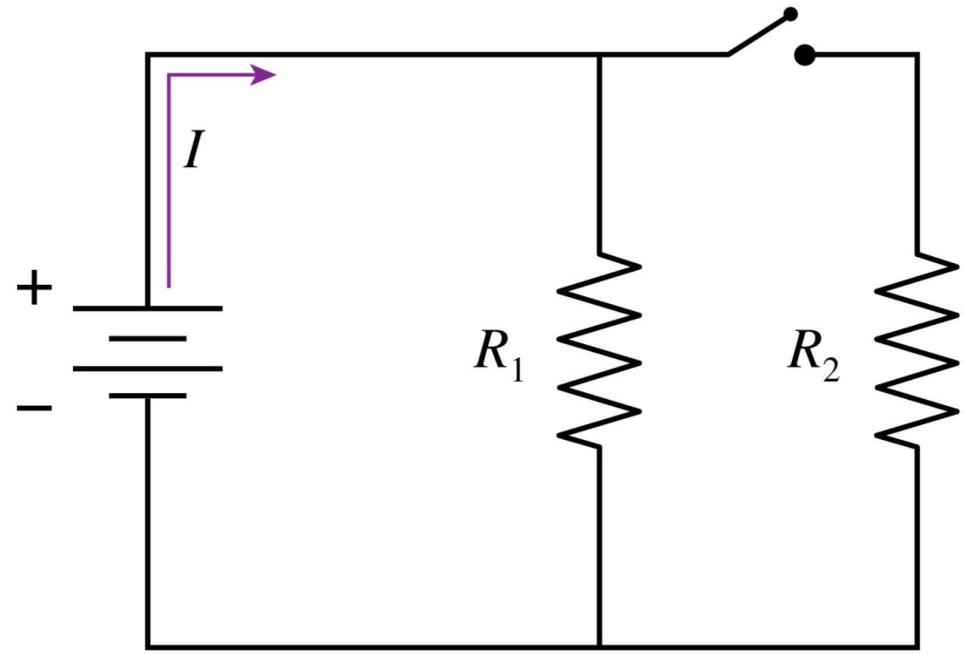
- We've emphasized so far that it's potential differences that we're interested in rather than absolute potentials
- It's useful, though, to tie a particular point of a circuit to a reference potential, i.e. to ground
  - plus a useful safety feature
- That way multiple circuits can be used at the same time and their reference potentials will be the same



Only potential differences are meaningful

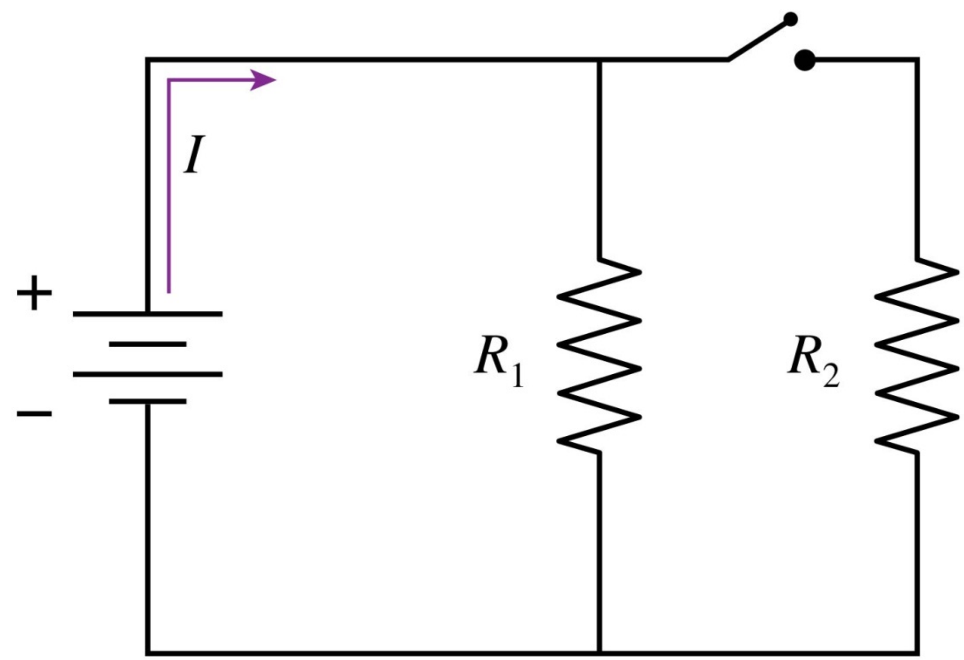


When the switch closes, the battery current



A. Increases.
B. Stays the same.
C. Decreases.

When the switch closes, the battery current



✔ **A. Increases.**

B. Stays the same.

C. Decreases.

Equivalent resistance decreases.
Potential difference is unchanged.

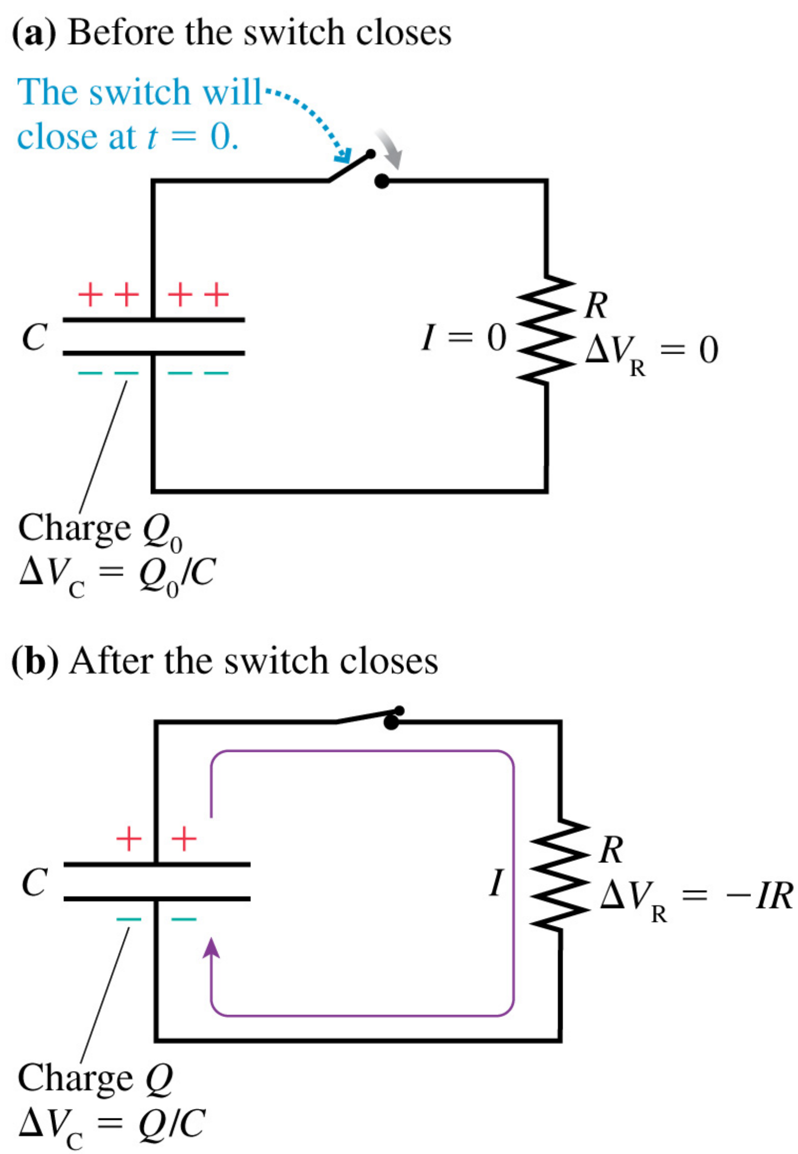
What if I add a capacitor to the circuit?

- After I close the switch, what current will flow?
- Do Kirchoff's laws still apply?
- Only loop rule relevant here

$$\Delta V_C + \Delta V_R = \frac{Q}{C} - IR = 0$$

  - note that the charge on the capacitor will change with time and the current through the resistor will change with time

$$I = -\frac{dQ}{dt}$$



Apply Kirchoff' s loop rule

$$\frac{dQ}{dt} + \frac{Q}{RC} = 0$$

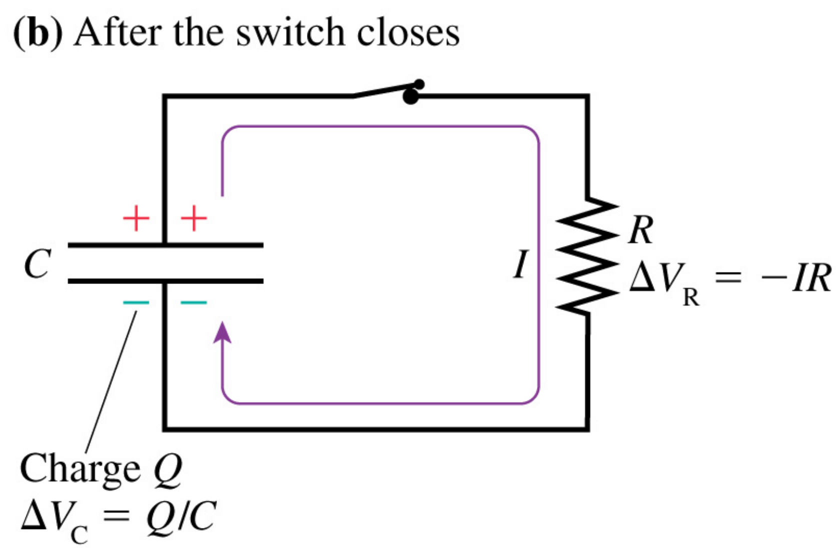
$$\frac{dQ}{Q} = -\frac{1}{RC}dt$$

$$\int_{Qo}^{Q} \frac{dQ}{Q} = -\frac{1}{RC}\int_{0}^{t} dt$$

$$\ln Q |_{Q_0}^{Q} = \ln Q - \ln Q_o = \ln\left(\frac{Q}{Q_o}\right) = -\frac{t}{RC}$$

$$Q = Q_o e^{-t/RC}$$

$$I = \frac{dQ}{dt} = -\frac{Q_o}{RC}e^{-t/RC} = I_o e^{-t/RC}$$



Q on capacitor (and thus voltage across capacitor) and current are decreasing expoentially

Kirchoff' s loop rule applies at all times

Time constant

- Define a time constant τ=RC so that we can write

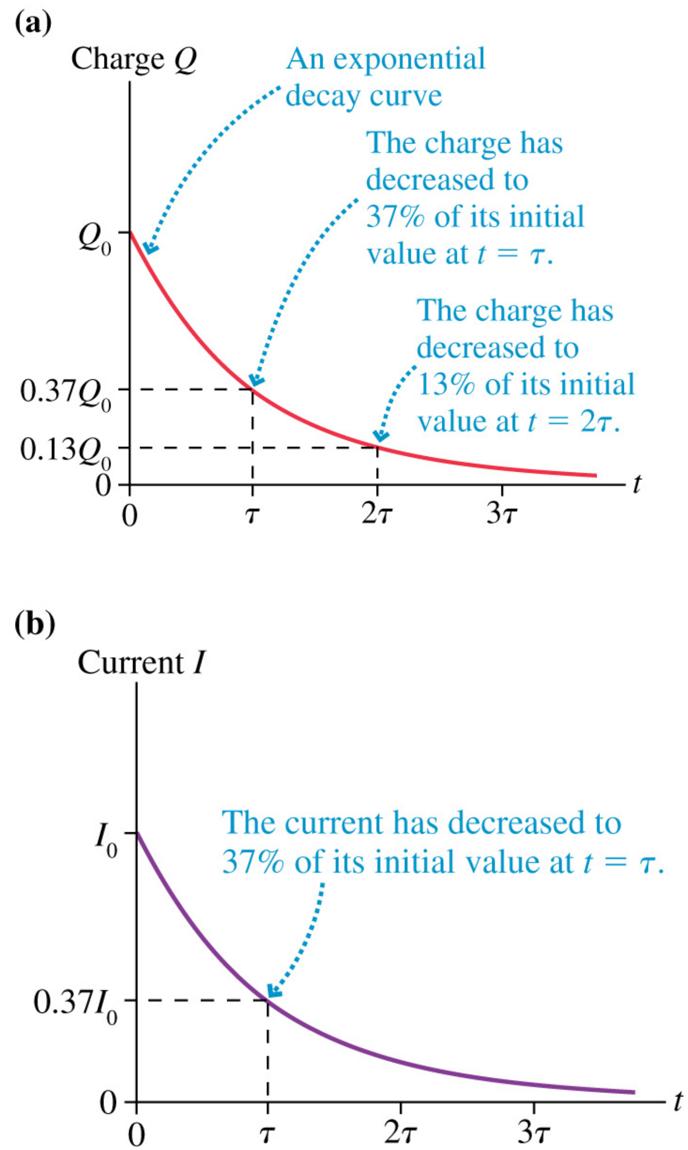
$$Q = Q_o e^{-t/\tau}$$
$$I = I_o e^{-t/\tau}$$

- RC has units of time(s)
- Consider when the current/charge has fallen to half of its initial value

$$\frac{I}{I_o} = e^{-t/\tau} = 0.5$$

$$t/\tau = \ln 0.5 = 0.693$$

$$t_{1/2} = 0.693\tau$$



Charging a capacitor

- The charge on the capacitor is given by

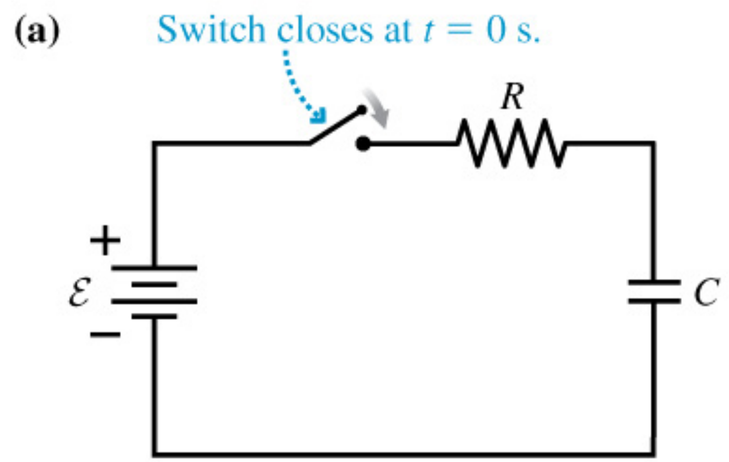
$$Q = Q_o(1 - e^{-t/\tau})$$

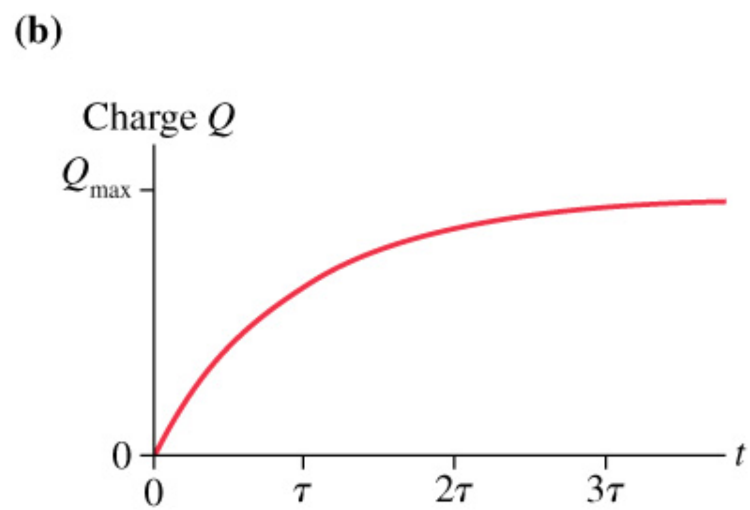
  - where Q_o is $C\varepsilon$

- And the current in the circuit is given by

$$I = \frac{dQ}{dt} = I_o e^{-t/\tau}$$

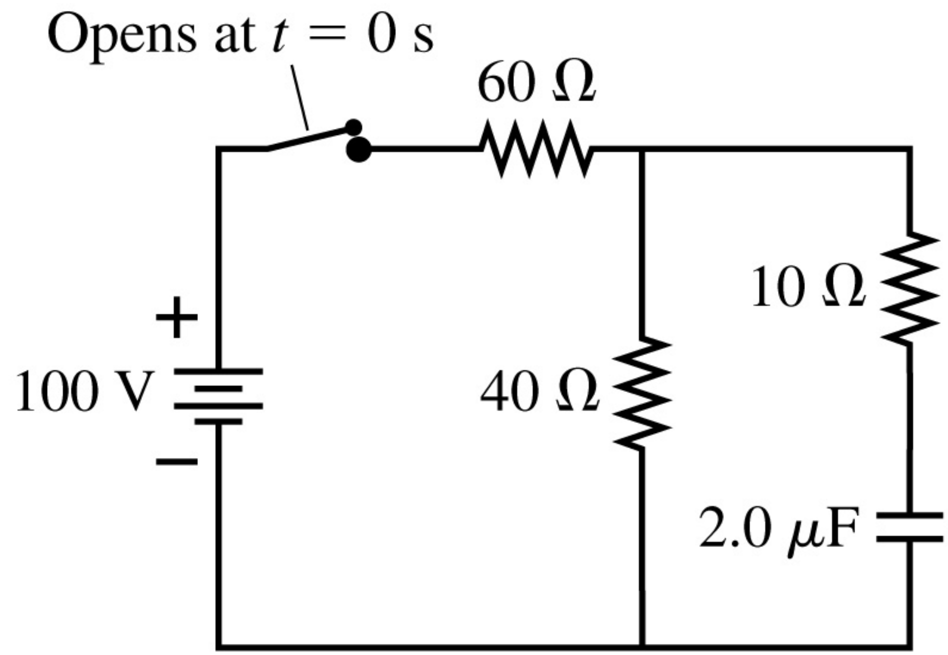
  - where $I_o = Q_o/RC$



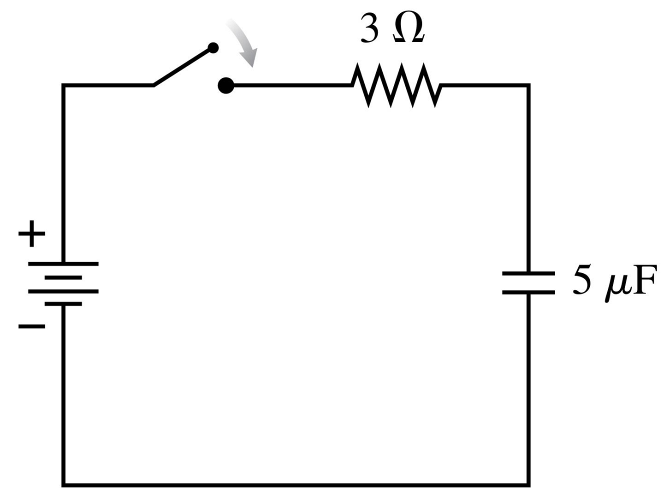


Example

- The switch in the circuit has been closed for a very long time
  - what is the charge on the capacitor?
  - the switch is then opened at t=0.
  - what is the maximum current at that time?
  - at what time has the capacitor decreased to 10% of its initial value?



The capacitor is initially unchanged. Immediately after the switch closes, the capacitor voltage is



A. 0 V.

B. Somewhere between 0 V and 6 V.

C. 6 V.

D. Undefined.

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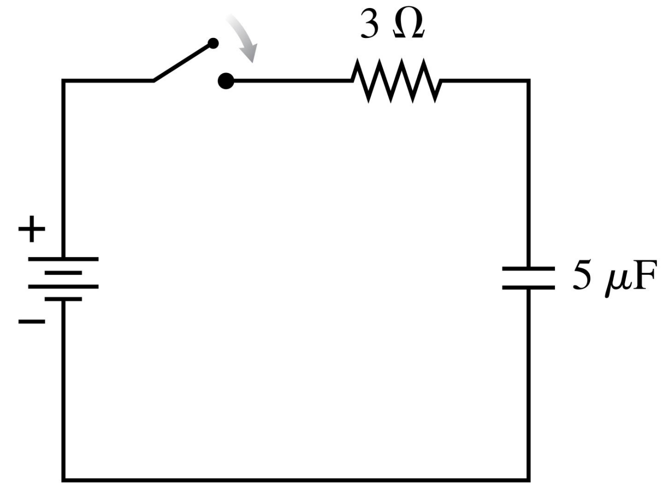


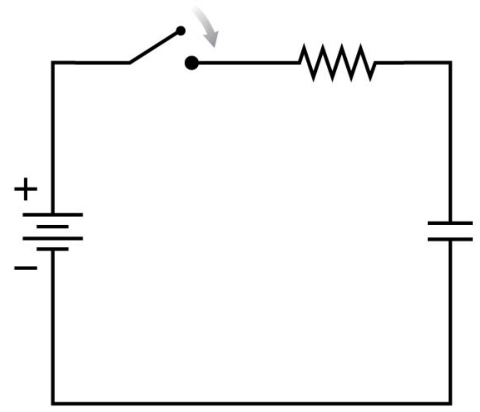
✔ **A. 0 V.**

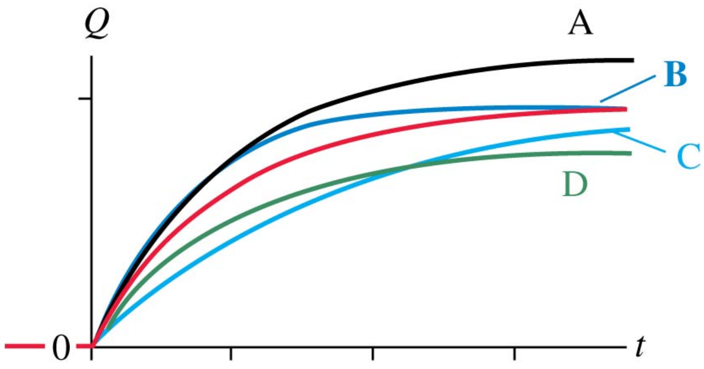
B. Somewhere between 0 V and 6 V.

C. 6 V.

D. Undefined.

The red curve shows how the capacitor charges after the switch is closed at $t = 0$. Which curve shows the capacitor charging if the value of the resistor is reduced?





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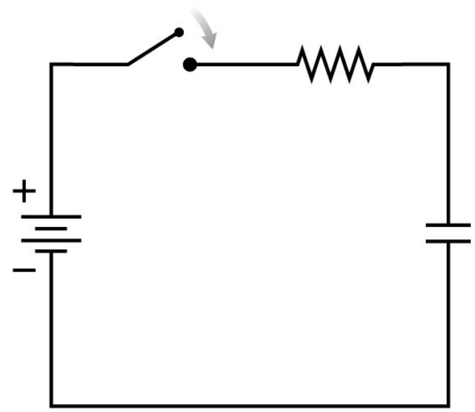

Smaller time constant.
Same ultimate amount of charge.