Chapter 19: Direct Current Circuits

- In this chapter we will explore circuits with batteries, resistors, and capacitors

- In this course, we will only consider:
Direct current – circuit where the current is constant in magnitude and direction

- Take an electronics or electrical engineering course to learn about
Alternating current – circuits where the current magnitude and direction is a sinusoidal function of time

$$I(t) = I_{\max} \sin(\omega t)$$

- Instead, we will consider power supplies, like a battery (e.g. in a car or flashlight)
- Let’s consider batteries in more detail
- To maintain a steady flow of charge through a circuit (DC or direct current), we need a “charge pump” – a device that – by doing work on the charge carries – maintains a potential difference between two points (e.g. terminals) of the circuit
- Such a device is called an <u>emf device</u> or is said to provide an emf ε
- A battery is a common emf device. Solar cells and fuel cells are other examples.
- emf $\equiv$ electromotive force. An outdated term. It is not a force, but a potential difference.

- Batteries are labeled by their emf ε, which is not the same as ΔV
- Batteries are not perfect conductors
- They also have some internal resistance, r, to the flow of charge
- Therefore, the potential difference (or terminal voltage) across the battery terminals is given by

$$\Delta V = \varepsilon - Ir$$

- ΔV and ε are only equal when I=0

  → open circuit
- Now, across the resistor

$$\Delta V = V_c - V_d = IR \Rightarrow \varepsilon = Ir + IR$$

- Or the circuit current is $$I = \frac{\varepsilon}{r + R}$$
- Usually, R>>r, so that the internal resistance can be neglected, but not always
- What is the power supplied to each element? From P=IΔV

$$I\varepsilon = I^2 r + I^2 R$$

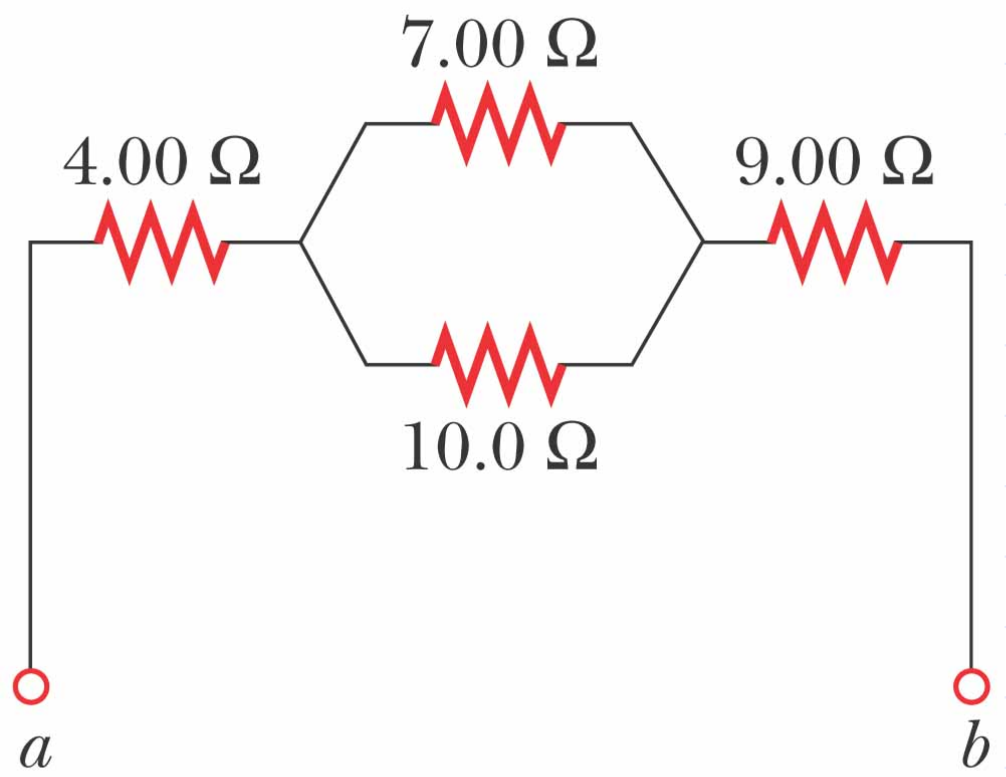
Power supplied by emf	Power lost to internal resistance	Power delivered to load

Example Problem

- An automobile battery has an emf of 12.6 V and an internal resistance of 0.080 Ω. The headlights together present equivalent resistance of 5.00 Ω (assumed constant). What is the potential difference across the headlight bulbs (a) when they are the only load on the battery and (b) when the starter motor is operated, taking an additional 35.0 A from the battery?

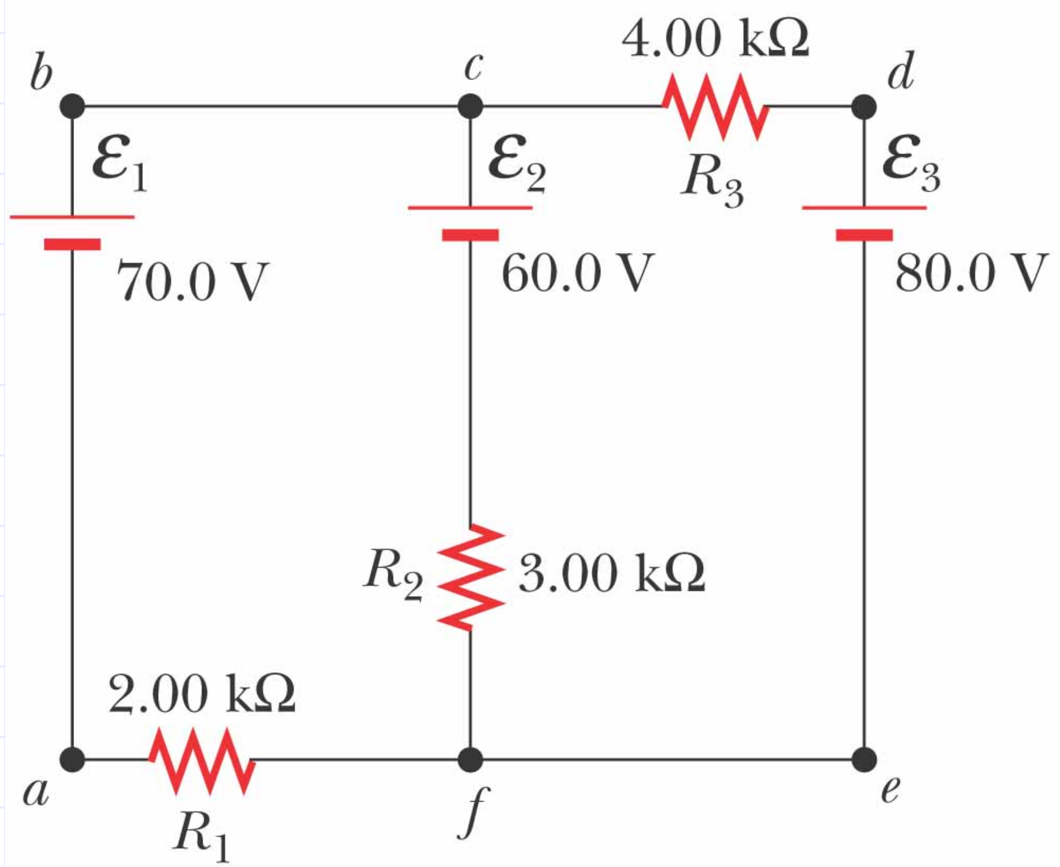
Example Problem

- (a) Find the equivalent resistance between points a and b in the figure. (b) A potential difference of 34.0 V is applied between points a and b. Calculate the current in each resistor.



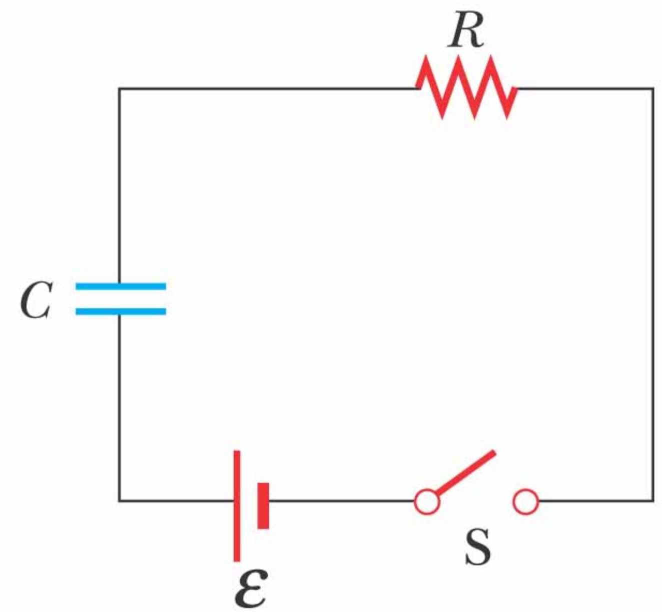
Example Problem

- Using Kirchhoff's rules, (a) find the current in each resistor in the figure. (b) Find the potential difference between points c and f. Which point is at the higher potential?



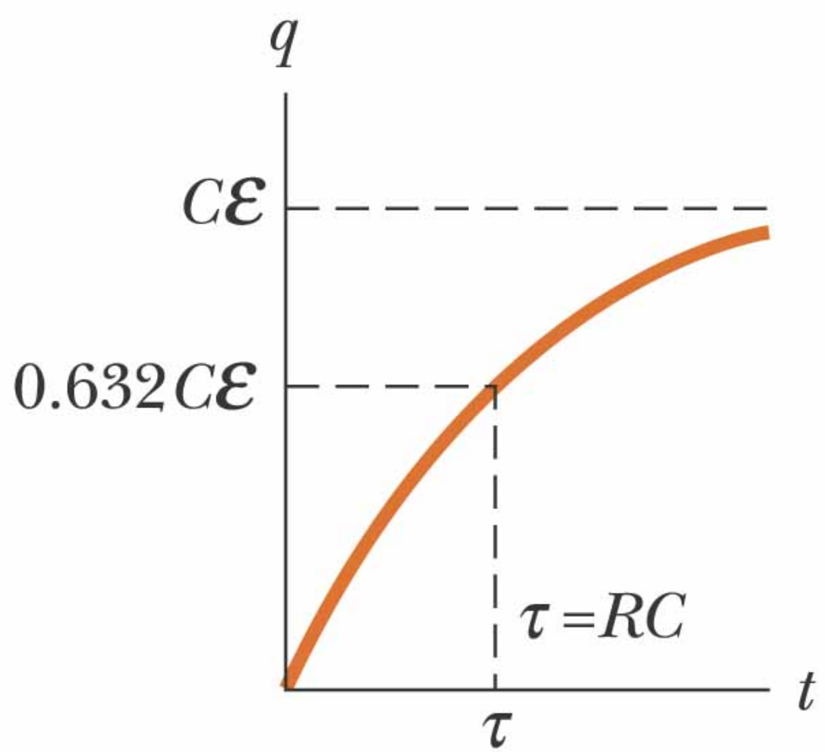
RC Circuits

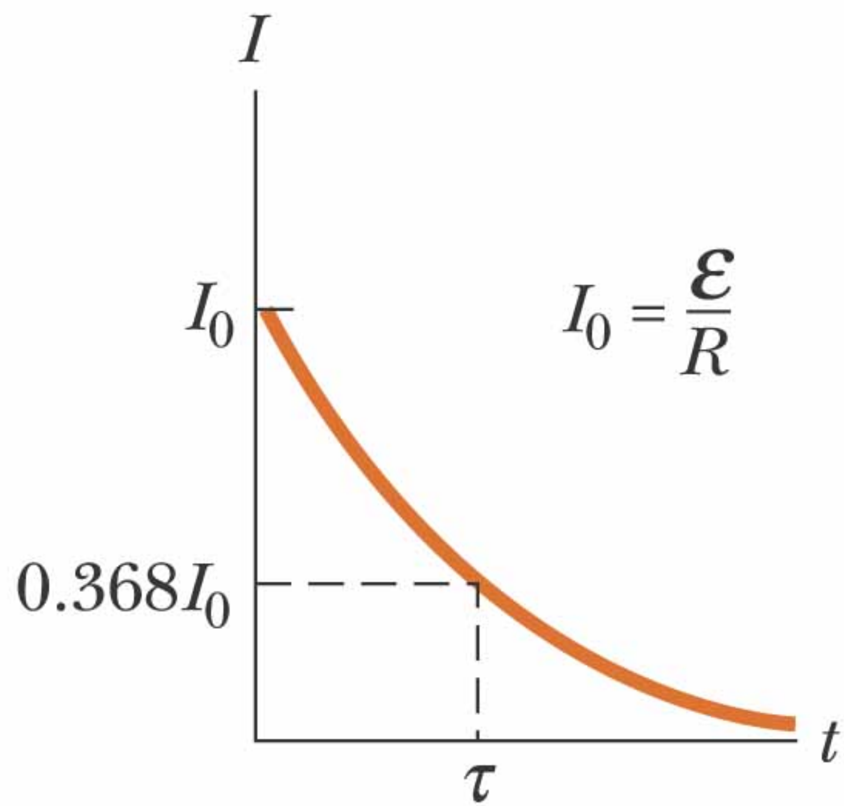
- For the circuits considered so far, the currents were constant
- Lets now consider a case where the current varies with time (not sinusoidal)
- Consider the resistor and capacitor wired in series
- The capacitor is initially uncharged
- An ideal emf source is attached (r=0)
- At t=0, throw the switch



Charge and current as a function of time for charging

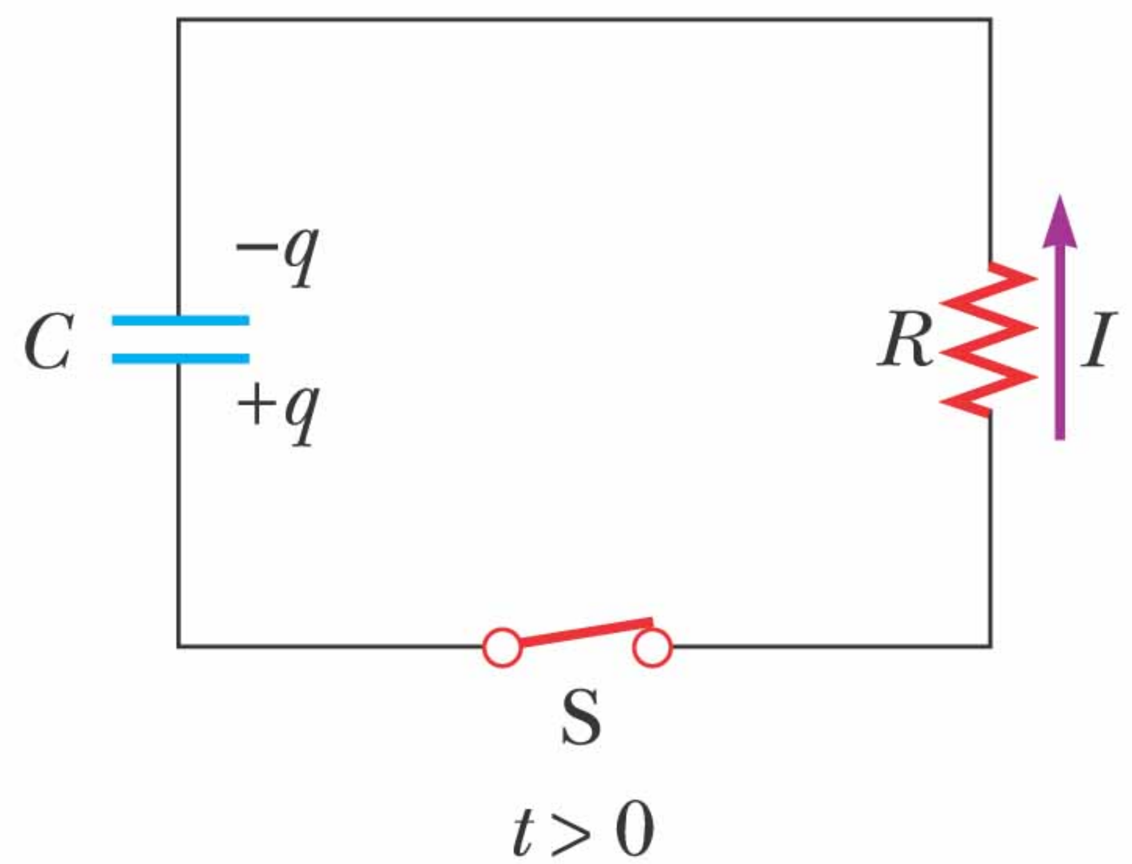
- Charge
- Current





Discharging the capacitor

- Remove emf from the circuit



Example Problem (for NASCAR fans)

- As a car rolls along the pavement, electrons move onto the tires and then the car body. The car stores the excess charge like one plate of a capacitor (let the other plate be the ground). When the car stops, the charge is discharged through the tires (which act as resistors) into the ground. If a conducting object (fuel dispenser) comes within centimeters of the car before all of the charge is discharged to the ground, the remaining charge can create a spark. If the available energy in the car (delivered by the spark) is greater than 50 mJ, the fuel can ignite. A race car can accumulate a large charge and, therefore a large potential difference (with the ground) of 30 kV. Assume the capacitance of the car-ground system is C=500 pF and each tire has a resistance of 100 GΩ. How long does it take the car to discharge through the tires to the ground for the remaining energy to be less than that needed to ignite the fuel?