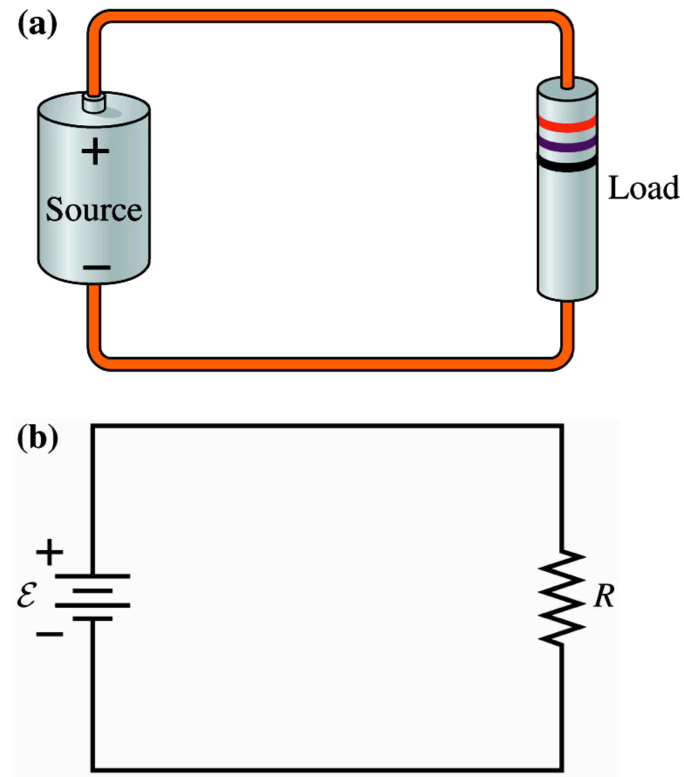
Physics 115

General Physics II



Session 22

Exam practice Q's

Circuits

Series and parallel R

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Lecture Schedule
(up to exam 2)

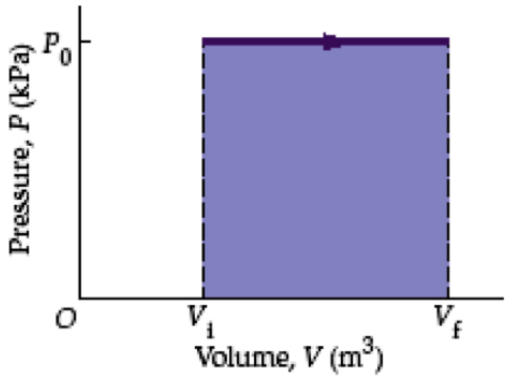
21-Apr	Mon	12	Specific Heats	18.4-18.6
22-Apr	Tues	13	Second Law	18.7-18.10
24-Apr	Thurs	14	Entropy	18.8-18.10
25-Apr	Fri	15	Charges	19.1-19.4
28-Apr	Mon	16	E field	19.5-19.66
29-Apr	Tues	17	Gauss law	19.7
1-May	Thurs	18	Electrical potential	20.1-20.3
2-May	Fri	19	Potential, conductors	20.4
5-May	Mon	20	Capacitors	20.5-20.6
6-May	Tues	21	Current	21.1-21.2
8-May	Thurs	22	Power, Series & Parallel Circuits	21.3-21.4
9-May	**Fri**		**EXAM 2 - Ch. 18,19,20**	

Today

Announcements

- Exam 2 is tomorrow!
  - Same format and procedures as last exam
  - Covers material discussed in class from Chs 18, 19, 20
    - NOT Ch. 21
  - We will review practice questions today

Practice questions



For 1-3: A monatomic ideal gas expands from an initial volume of 30.0 L to a final volume of 65.0 L, at a constant pressure of 110 kPa.

1. How much work is done by the gas?

A) 3.85 kJ
B) 10.4 kJ
C) 3850 kJ
D) 10.4 MJ
E) 3.85 MJ

Answer: A

$$\Delta U = Q_{IN} - W_{BY}$$

$$W = P(V_f - V_i) = 110kPa(35L) = 110kPa(0.035m^3) = 3.85kJ$$

2. Is heat added to or taken away from the gas?
A) Heat is added to the system.
B) Heat is taken from the system.
C) Unable to determine with info given.

Answer: A

$$Q_{IN} = \Delta U + W_{BY}, \quad W = P(V_f - V_i), \quad PV = NkT$$

$$Q_{IN} = \frac{3}{2}Nk\Delta T + P\Delta V = \frac{3}{2}P\Delta V + P\Delta V = \frac{5}{2}P\Delta V$$

$$\Delta V > 0 \rightarrow Q_{IN} > 0$$

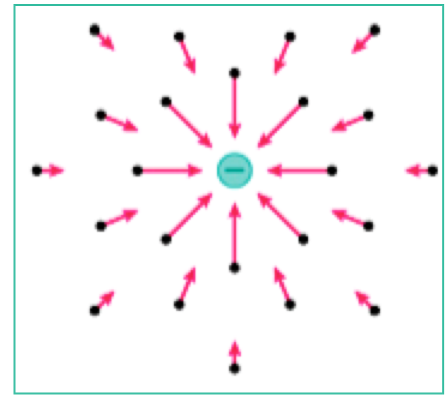
3. How much heat is transferred (magnitude only, regardless of direction you gave in previous question)
A) 3.85 kJ
B) 9.62 kJ
C) 3.85 MJ
D) 9.6 MJ
E) None of the above

$$Q_{IN} = \Delta U + W_{BY}, \quad W = P(V_f - V_i), \quad PV = NkT$$

$$Q_{IN} = \frac{5}{2}P\Delta V = \frac{5}{2}110kPa(0.035m^3) = 9.625kJ$$

The electric field at $x = 15.0$ cm and $y = 0$ points in the positive x direction, with a magnitude of 5.00 N/C. At the point $x = 35.0$ cm and $y = 0$, the electric field points in the positive x direction with a magnitude of 25.0 N/C.
Assume that this electric field is produced by a single, point charge.
4. What is the location of the point charge:

A) At x < 0
B) At x between 0 and 15 cm
C) At x between 15 and 35 cm
D) At x > 35 cm



$(x, y) = (\ 51.2,\ 0\ )$ cm

5. What is the sign of the point charge.

A) Positive
B) Negative

E points in +x direction, but is larger at 35 cm than 15 cm.
So Q must be negative and located at x > 35cm.

-7.28e-11 C

Extra practice: we can find the magnitude of the charge also:

$$E = kQ/r^2 \Rightarrow 5N/C = kQ/(x-15)^2,\quad 25N/C = kQ/(x-35)^2$$

$$kQ = (5N/C)(x-15)^2 = (25N/C)(x-35)^2$$

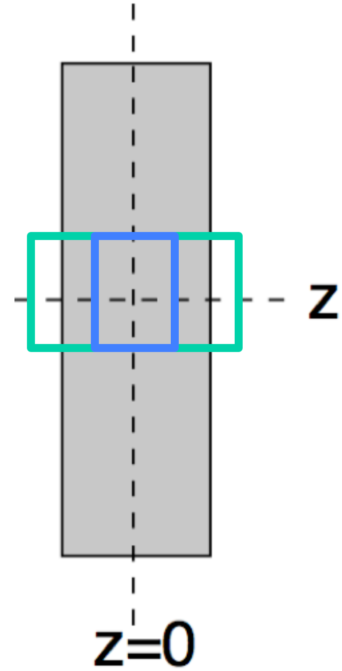
$$5x^2 - 150x + 1125 = 25x^2 - 1750x + 30625$$

$$20x^2 - 1600x + 29500 = 0 \Rightarrow x = 1600 \pm \sqrt{200000}/40$$

$x = 28.8cm < 35cm$ so cannot be correct: use other solution

$$x = 51.2cm \rightarrow Q = (5N/C)(x-15)^2/k = 7.27 \times 10^{-7} C$$

For questions 6-7: A slab of insulating material whose thickness is 10 cm has a uniform positive charge density ρ throughout its volume. The slab is very large in the x and y directions. Its center is at $z = 0$.



6. (4 pts.) What is the magnitude of the electric field inside the slab at $0 < z < 5$ cm ?

A. $\rho/(2\varepsilon_0)$
B. ρ/ε_0
C. $\rho z/(2\varepsilon_0)$
D. $2\rho z/\varepsilon_0$
E. $\rho z/\varepsilon_0$

Ans: E.
Consider Gaussian surface = cylinder of area A, length 2z, centered on z=0.
E field points in the +/- z direction (outward from centerline) by symmetry.

Flux $\Phi = EA = Q$ enclosed / ε_0
Q enclosed = $\rho A2z$, flux through cylinder =E(2A) $\rightarrow$ $E(\pm z) = \rho z/\varepsilon_0$

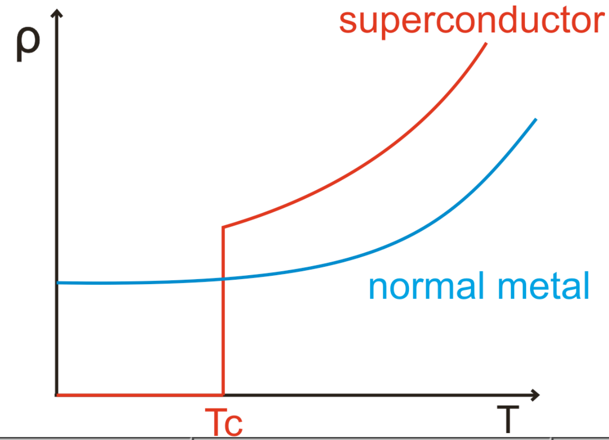
7. (4 pts.) What is the magnitude (V/m) of the electric field outside the slab at $z > 5$ cm ?

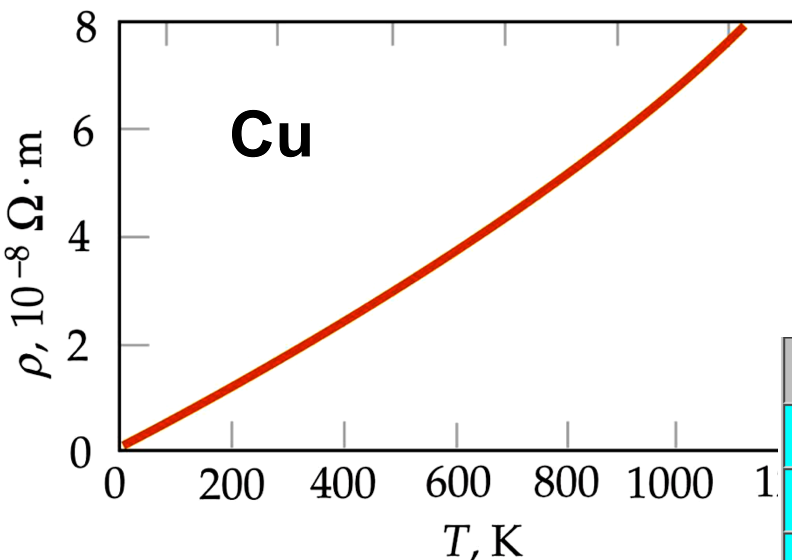
A. $0.05\rho/\varepsilon_0$
B. $0.1\rho/\varepsilon_0$
C. $\rho z/(2\varepsilon_0)$
D. $2\rho z/\varepsilon_0$
E. ρ/ε_0

Ans: A. Outside, Q enclosed = $\rho A(0.1\text{m})$, flux= E2A $\rightarrow$ $E(\pm z) = \rho(0.1\text{m})/2\varepsilon_0$

Resistivity and Temperature

- Resistivity of most materials depends upon temperature
  - Usually, cooler = smaller resisitivity
- But at very low temperatures, $\rho \rightarrow 0$ (really, zero)
  - Below some critical temperature T_C



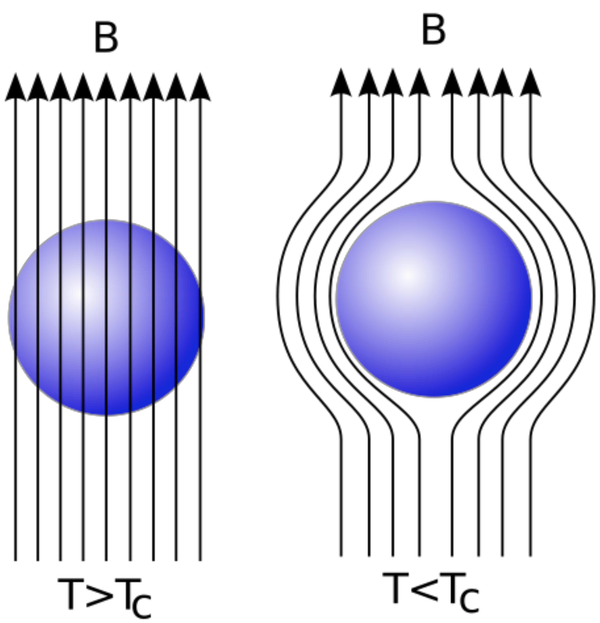


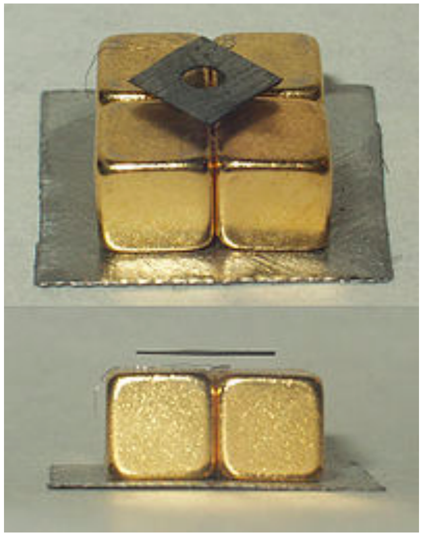
Material	Type	T_c(K)
Zinc	metal	0.88
Aluminum	metal	1.19
Tin	metal	3.72
Mercury	metal	4.15
$YBa_2Cu_3O_7$	ceramic	90
TlBaCaCuO	ceramic	125

"High temperature superconductors"

Superconductors

- One feature of a superconductor: magnetic fields cannot exist inside
  - "Pushes out" any magnetic field present
    - Use SCs to "levitate" magnets → frictionless bearings
  - We'll discuss magnetic fields (***B***) soon...





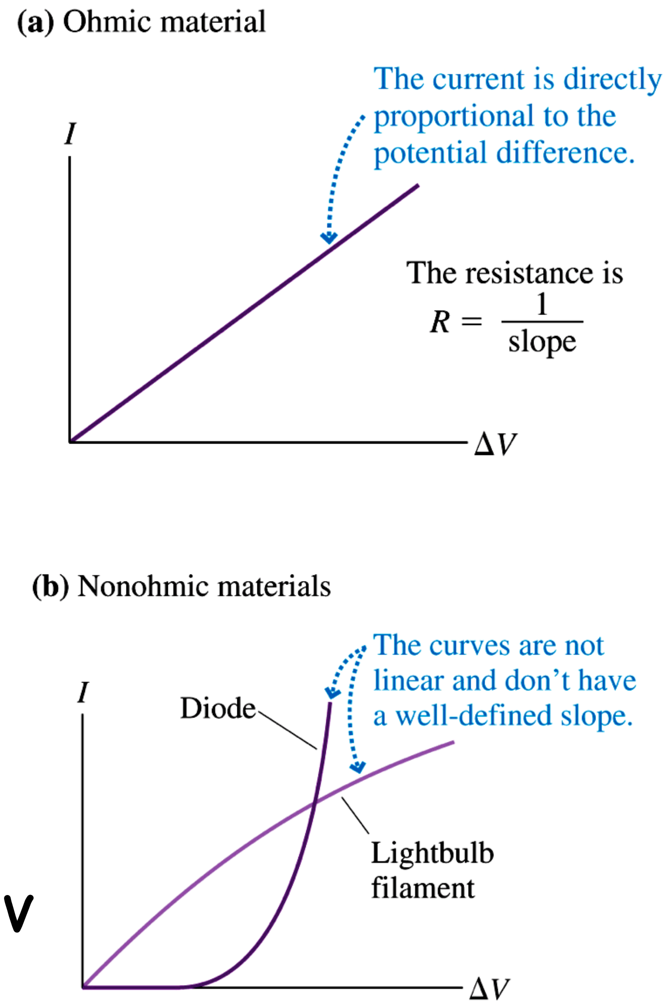
Ohmic and Non-Ohmic

Ohm's Law is just a useful rule about the *approximately linear* I vs V behavior of some materials under some circumstances.

Non-linear conductors are called "non-ohmic"

Important non-ohmic devices:

1. Batteries, where **ΔV=E** is determined by chemical reactions independent of **I**;
2. Semiconductors, where **I** vs. **V** is designed to be very nonlinear;
3. Light bulbs, where **R** changes as the bulb gets hotter (brighter)
4. Capacitors, where the relation between **I** and **V** differs from that of a resistor (next week).



Energy and power in electric circuits

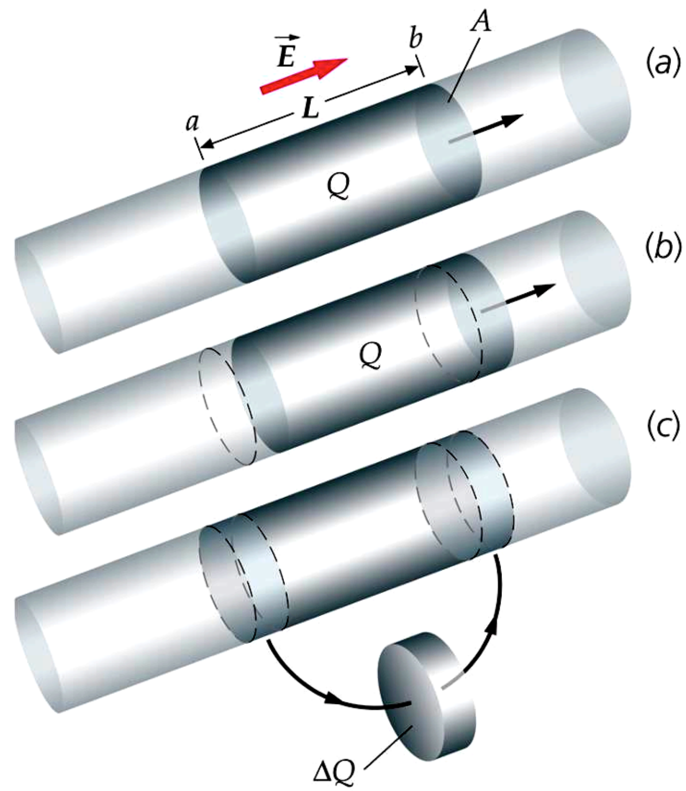
Fluid flow analogy: push a parcel of water against P
Or ... Push a parcel of charge against E (across ΔV)

$$\Delta U = \Delta Q(V_b - V_a) = -\Delta Q\, V$$

$$\frac{\Delta U}{\Delta t} = power : P = \frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} V = I\, V$$

Using Ohm's Law
to relate I, V and R

$$P = IV = I^2 R = V^2 / R$$



Units for electrical power, and energy

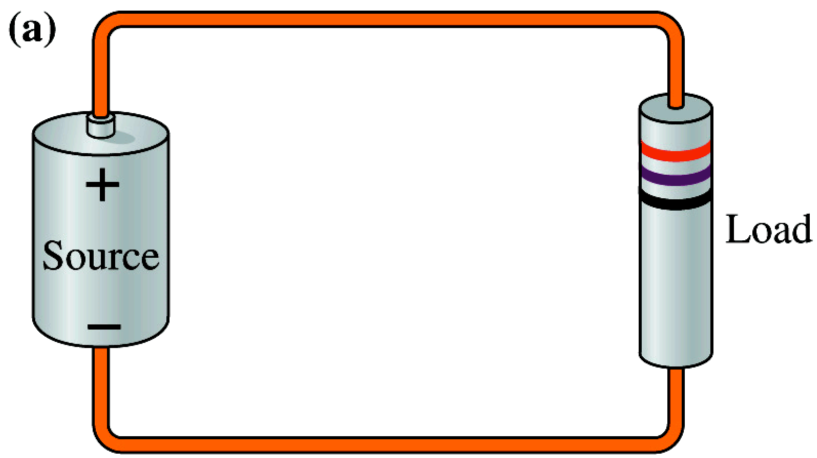
$$\text{Power units} \cdots \text{ watts} = \text{W} = \text{volt-ampere} = \text{J/s}$$

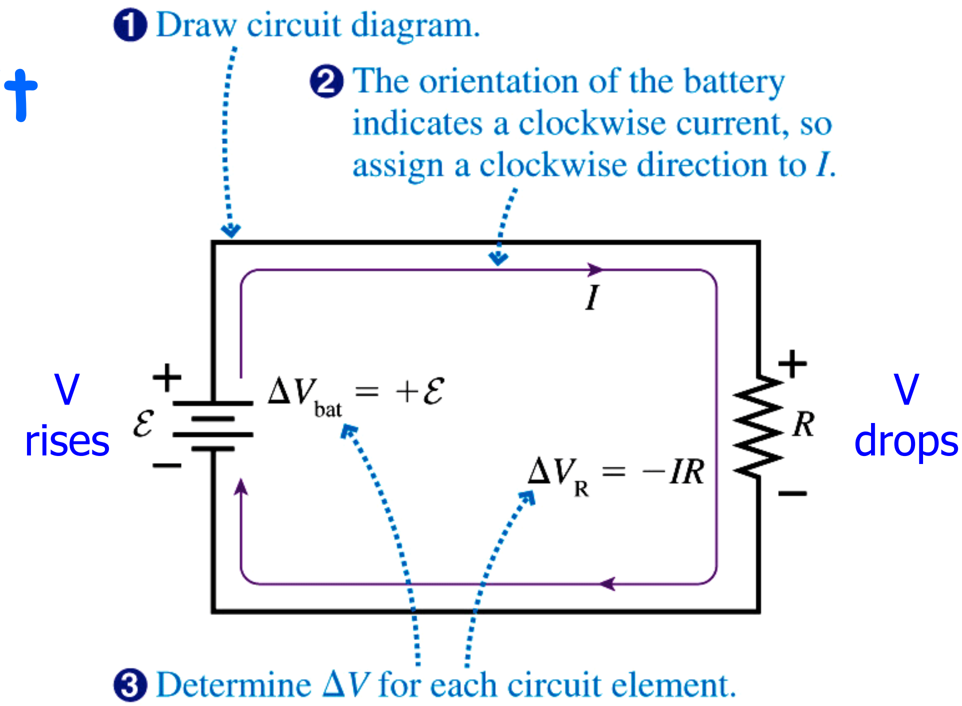
$$\text{Energy units L} \quad 1 \text{ kilowatt-hour} = (1.0\times10^3 \text{ W})(3600 \text{ s})$$
$$= 3.6\times10^6 \text{ J}$$

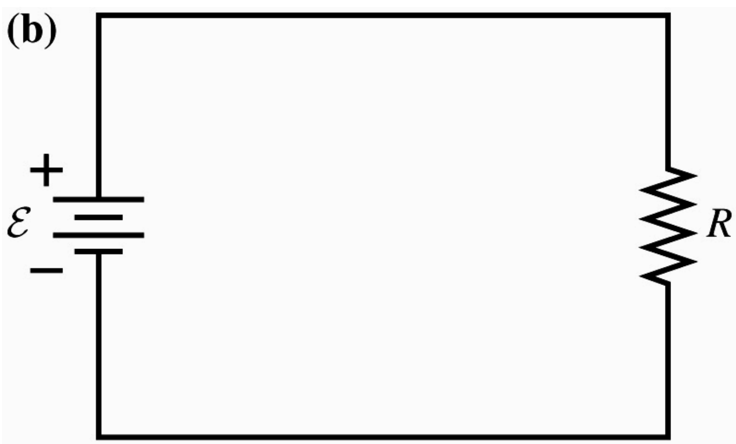
Seattle City Light charges about 5¢ per kilowatt-hour of electrical energy (for the first 10 kW-hr each day), so one million joules (1 MJ) of electrical energy costs about 1.4¢. (Remarkably cheap! Lucky for us: we have hydro power – no fossil fuels, gravity is free)

If you operate a 1500 W hair dryer for 10 minutes, you use 0.25 kilowatt hours or 0.9×10^6 J of energy, which adds about 1.25¢ to your electric bill. (but if you use a lot of power that day, it costs twice as much)

Basic Electrical Circuit



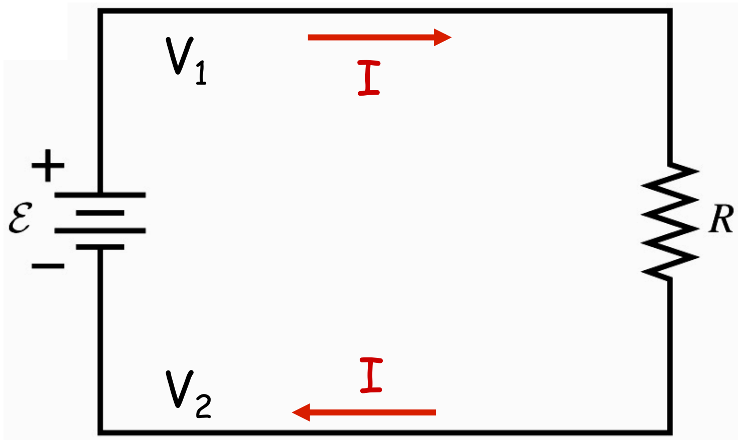


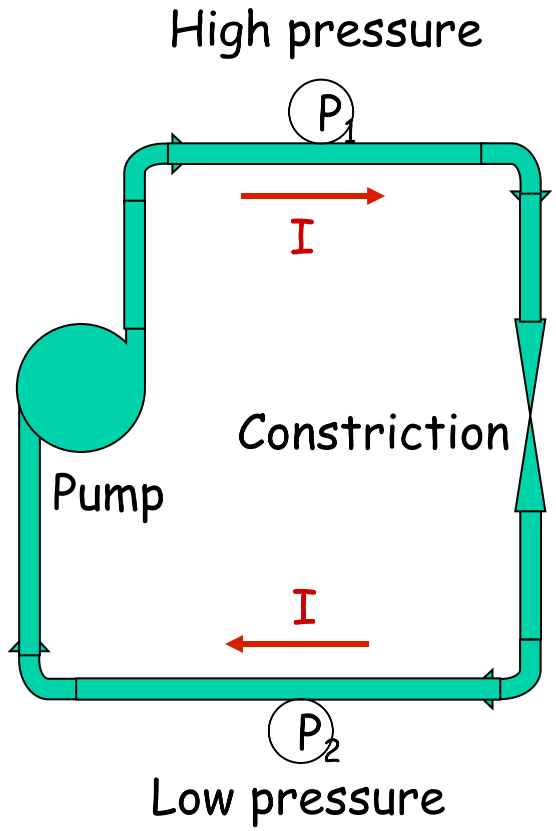


Voltage drop across resistor: V= -IR
Voltage rise across battery: ΔV =+ $\mathcal{E}$
Energy conservation: must have $\mathcal{E}$ + V =0
(trip around the circuit returns to same place;
E is a conservative force, so net potential difference must be zero)

$$\Delta V_{bat} = +\mathcal{E}; \quad \Delta V_R = V_{downstream} - V_{upstream} = -IR \qquad \mathcal{E} - IR = 0; \quad I = \frac{\mathcal{E}}{R}$$

Plumber's Analogy to electrical circuit





"Plumber's analogy" of this circuit: a pump (=battery) pumping water in a closed loop of pipe that includes a constriction (=resistor).

- The pressure (=V_1) in the upper part of the loop is higher than in the lower part (=V_2).
- There is a pressure drop (=V_1-V_2) across the constriction and a pressure rise across the pump.
- The water flow I is the same at all points around the loop.

Pump = Battery
Constriction = Resistor
Pressure = Potential
Water Flow =Current

The Current in a Wire

What is the current in a 1.0 mm diameter 10.0 cm long copper wire that is attached to the terminals of a 1.5 V battery.

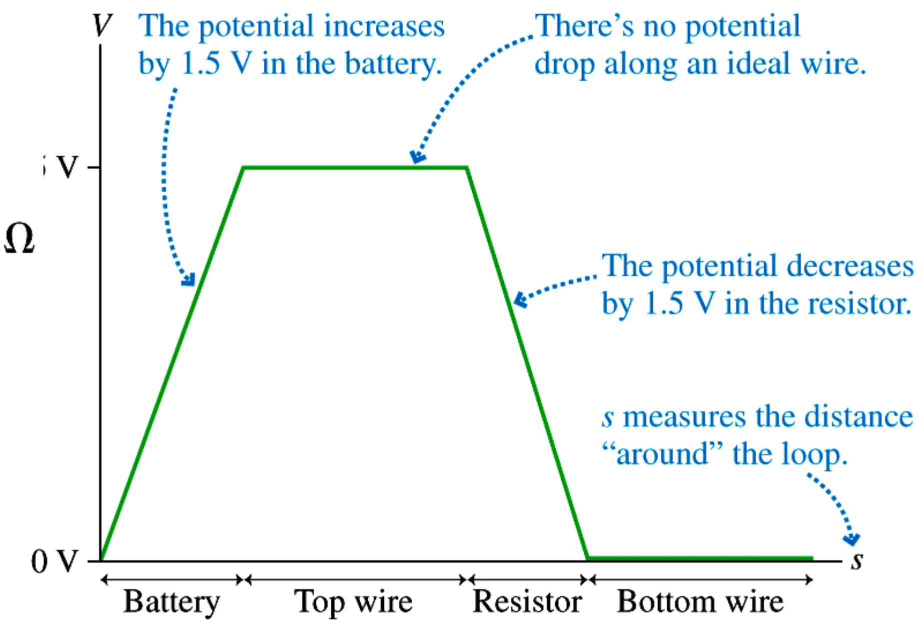
$$R = \rho L / A = \rho L / (\pi r^2) = (1.7 \times 10^{-8}\ \Omega\,\mathrm{m})(0.10\ \mathrm{m}) / \pi (0.0005\ \mathrm{m})^2$$

$$= 2.2 \times 10^{-3}\ \Omega$$

$$I = \Delta V / R = (1.5\ \mathrm{V}) / (2.2 \times 10^{-3}\ \Omega) = 680\ \mathrm{A}$$

Big current! The wire will probably melt.
If the wire were instead 100m long:
R=2.2 ohms, I = 0.68 Amps (survivable)

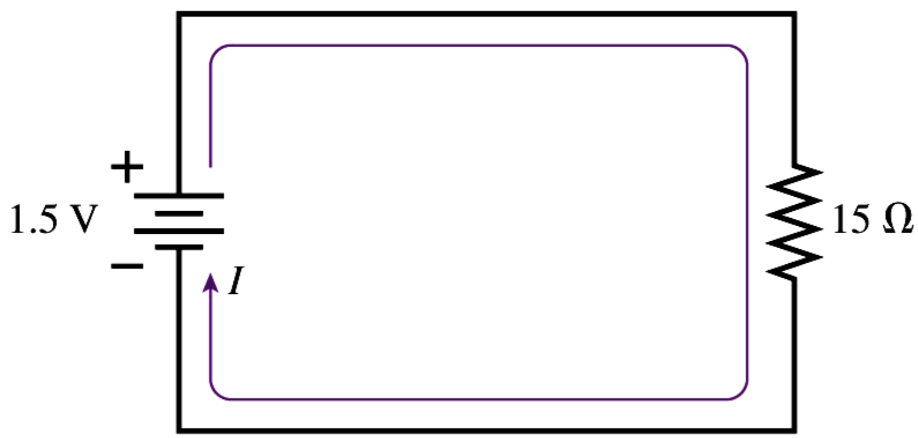
Example:
A Single-Resistor Circuit



$$I = \frac{\mathcal{E}}{R} = \frac{(1.5\ \text{V})}{(15\ \Omega)} = 0.10\ \text{A}$$

$$\Delta V_{\text{bat}} = +\mathcal{E} = +1.5\ \text{V};\ \ \Delta V_{\text{R}} = -\mathcal{E} = -1.5\ \text{V}$$

Energy and Power in a simple circuit



$$P = I\mathcal{E} = I^2 R = \mathcal{E}^2 / R$$

What is the power dissipated in the resistor?

Voltage drop across resistor $\Delta V = -\mathcal{E}$

$P = I\,V = I^2 R = V^2 / R = 0.15\text{W}$

Notice: $P \propto I^2 R$ OR $\propto V^2 / R$

...Depends upon info given

Example: A 15 Ω load resistance is connected across a 1.5 V battery. How much power is delivered by the battery?

$$I = \frac{\mathcal{E}}{R} = \frac{(1.5\text{ V})}{(15\ \Omega)} = 0.1\text{ A}$$

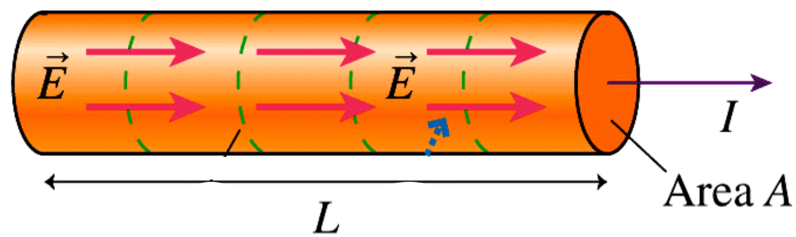
$$P = I\mathcal{E} = (0.1\text{ A})(1.5\text{ V}) = 0.15\text{ W}$$

$$P = \mathcal{E}^2 / R = (1.5\text{ V})^2 / (15\Omega) = 0.15\text{W}$$

Resistors in Series and Parallel

Normal conductor that carries current across its length forms a ***resistor***, a circuit element with ***electrical resistance R defined by:***

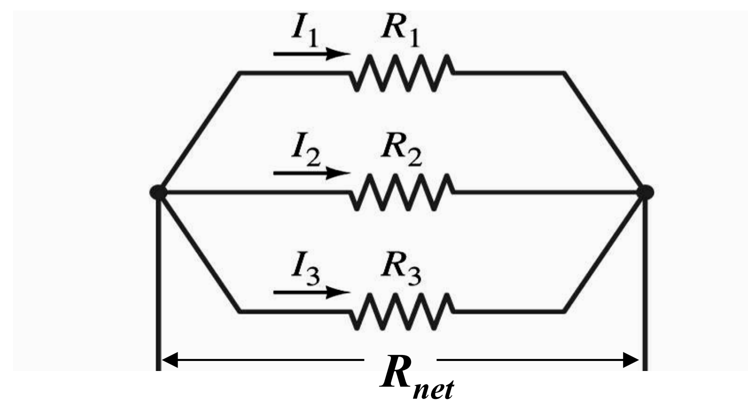
ρ = Resistivity of material



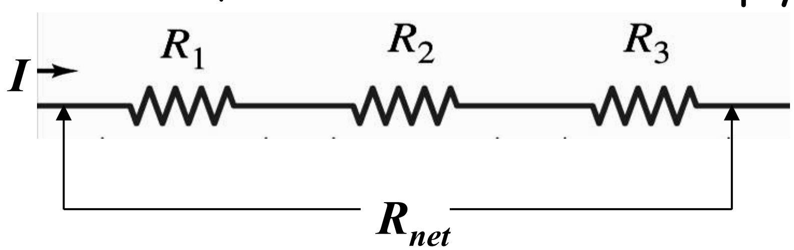
$$R \equiv \rho L/A$$

where L is the length of the conductor and A is its cross sectional area. R has units of ***ohms*** **(Ω = V/A)**.

Multiple resistors may be combined in two ways:



in ***series***, where resistances simply add, or



Series Connection [ΣL]:

$$R_{net} = R_1 + R_2 + R_3$$

in ***parallel***, where inverse resistances (= conductances) add.

Parallel Connection [Σ(1/A)]:

$$\frac{1}{R_{net}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Example of R's in series

- Suppose 3 identical R's are in series, each one is 100 Ω, and battery provides $\mathcal{E}$ =12V
  - Each R sees the same I passing through it
  - Each R drops $V_j = I R_j$

  This is why we sum R's for series resistors:

  $\mathcal{E} = I (R_1 + R_2 + R_3)$

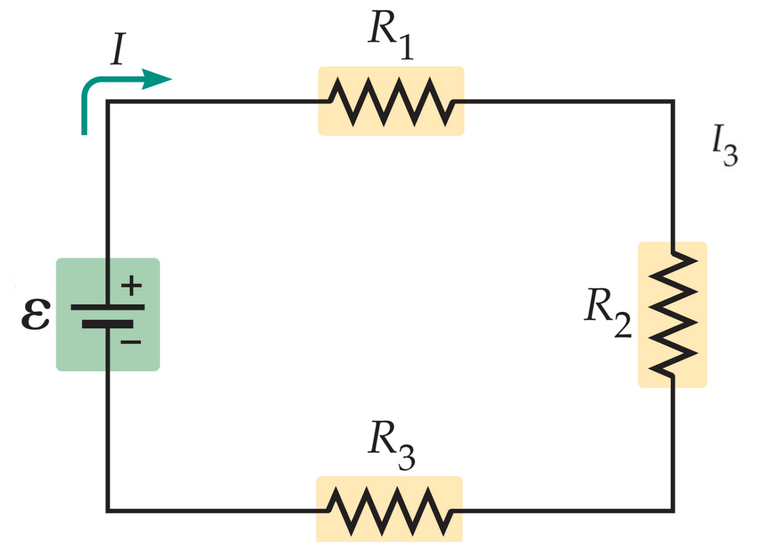
  $R_{eq} = R_1 + R_2 + R_3$

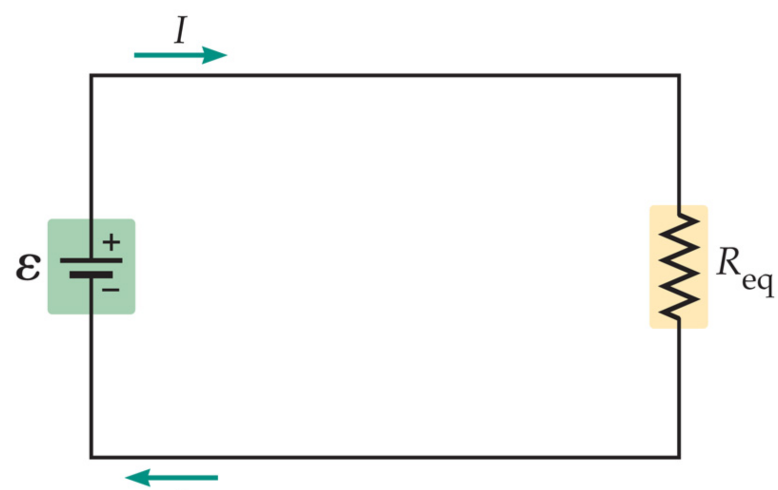
  Notice: net R is larger than any single R: all join to restrict I

  $I = 12V/300\ \Omega = 0.04\ A = I_1 = I_2 = I_3$

  - Notice: effective R seen by battery is $R = \mathcal{E} / I = 12V/0.04A$

    $R_{eq} = 300\ \Omega$





(b)

Example of parallel R's

- Suppose 3 identical R's are in parallel, each one is 100 Ω, and battery provides $\mathcal{E}$ =12V
  - Each R sees 12V potential difference across its terminals
  - Each R draws $I_j = \mathcal{E} / R$

  I_1 = 12V/100 Ω =0.12 A $=I_2 = I_3$
  - Total current I = 0.36 A
  - Notice: effective R seen by battery is R=$\mathcal{E}$ / I = 12V/0.36A

    R_{eq}= 33.3 Ω

  That is why we sum (1/R)'s for paralllel resistors:

  $I = I_1 + I_2 + I_3$

  → $\mathcal{E} / R = \mathcal{E} (1/R_1 + 1/R_2 + 1/R_3)$

  Notice: net R is smaller than any single R: multiple paths for I