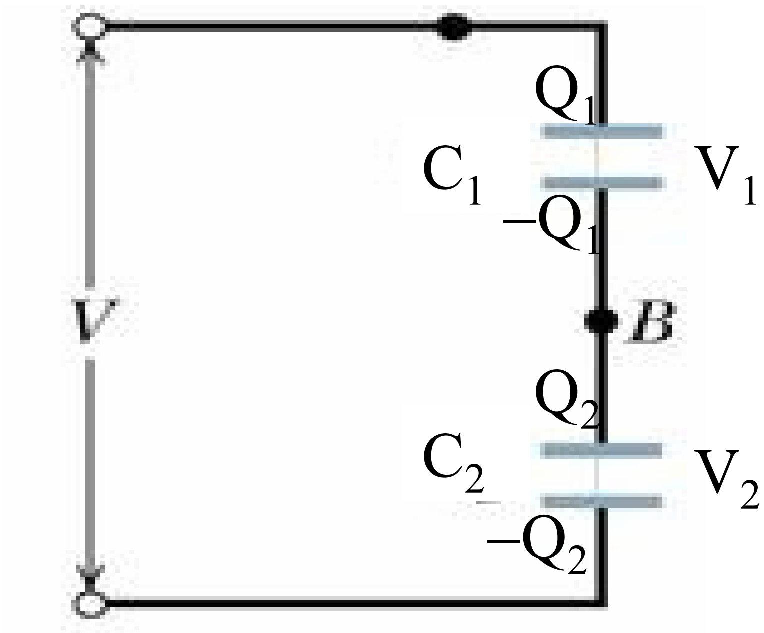
Announcements

1. Tutorial sessions Monday-Thursday evenings Olin 103
   Section B review sessions Tuesday 6-7 in Olin 101
2. First hour exam – Friday, Feb. 3rd
   - May bring one 8.5 x 11 inch page with equations
   - Practice problems on line and in text
3. Physics Colloquium Thursday 1/27/05 at 4 PM
   "Integrated Coal Gasification Combined Cycle Power Plants - A Cleaner Coal-to-Electricity Option"
4. Topics for today (beginning of Chapter 27)
   a) Electric current
   b) Resistivity & conductivity

Peer instruction question

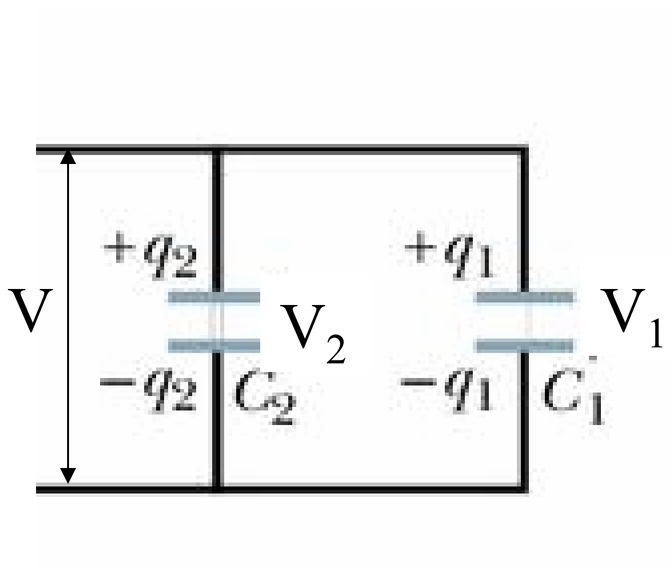


Consider the circuit shown in the diagram and assume $C_1 > C_2$. Which of the following statements are true?

(A) $V_1 > V_2$ (B) $V_2 > V_1$

(C) $Q_1 > Q_2$ (D) $Q_2 > Q_1$

Peer instruction question



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(C) $q_1>q_2$ (D) $q_2>q_1$

Electrical current

Up to now, we have been mostly concerned with stationary charges. Now we will focus our attention on moving charges – specifically charges moving in a conductor.

Static properties of a conducting material:

- Mobile charges within conductor move in response to forces applied to them
  - Charges tend to migrate to surfaces of conductors
  - $E=0$ and V=constant within interior of conductor

Dynamical properties of a conducting material:

- Mobile charges within conductor move in response to forces applied to them
  - Charges can flow within conductor
  - $E\neq 0$ and $V\neq$constant within interior of conductor

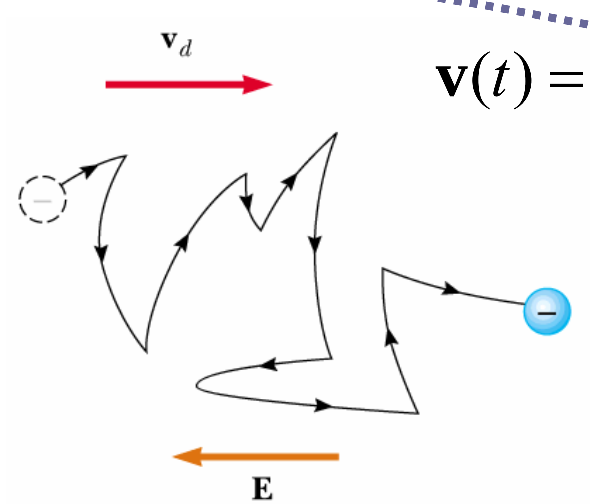
Quantitative measure of electrical current

$$I = \frac{dQ}{dt}$$ Units of I = Coulombs/s ≡ Ampere

Microscopic picture of electrical current:

E

$-q$



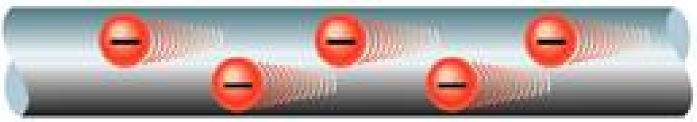
$$\mathbf{v}(t) = \mathbf{v}_i - \frac{q\mathbf{E}}{m} t$$

After accelerating for some time, the electron will collide and change direction

$$\Rightarrow \quad v_d = \frac{qE}{m}\tau$$

time between collisions

Online Quiz for Lecture 6
Current -- Jan. 24, 2005

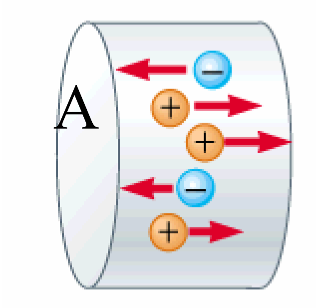


The figure here shows conduction electrons moving leftward through a wire. What is the direction (leftward -- (A) or rightward -- (B)) of the following:

1. The current i? **right**
2. The current density J? **right**
3. The electric field within the wire? **right**

Expression for the current in terms of the drift velocity v_d

E



ΔL

$$I = qnAv_d$$

number of electrons per unit volume

$$v_d = \frac{qE}{m}\tau$$

In terms of the potential: $\Delta V = \Delta L\ E$ ➔ $v_d = \dfrac{q\Delta V}{m\Delta L}\tau$

$$I = \underbrace{\left(\frac{q^2 n\tau A}{m\Delta L}\right)}\Delta V$$

$\equiv$ *1/R* (constant for each material)

Ohm's law (actually an approximation, not really a "law")

$\Delta V = I R$ units: R = volts/amp ≡ ohm (Ω)

$$R = \frac{m\Delta L}{q^2 n \tau A} \equiv \rho \frac{\Delta L}{A}$$

Typical resistances for $A=3\text{x}10^{-6}\text{m}^2$; $\Delta L=0.01\text{m}$

Material	Resistance (Ω)
Copper	5.6×10^{-5}
Carbon	1.2×10^{-1}
Silicon	$\sim 8.3 \times 10^{6}$
Glass	$\sim 10^{13}$

Summary:

Ohm's law: $\Delta V = I\,R$

$$R = \rho \frac{\Delta L}{A}$$

$$\text{Resistivity}: \; \rho = \frac{m}{q^2 n \tau}$$

In terms of electric field

$$E = \frac{\Delta V}{\Delta L} = \frac{IR}{\Delta L}\frac{\mathrm{A}}{\mathrm{A}} = \frac{I}{A}\frac{RA}{\Delta L} = \frac{I}{A}\rho \equiv J\rho$$

$$\text{Defining conductivity}: \quad \sigma \equiv \frac{1}{\rho} = \frac{q^2 n \tau}{m}$$

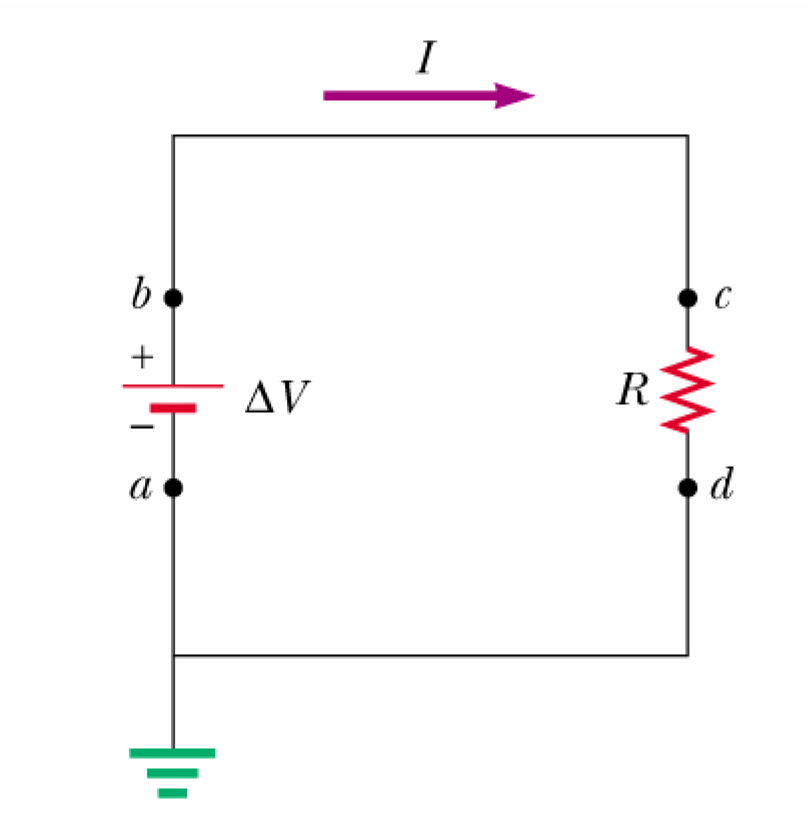
$$\Rightarrow J = \sigma E$$

For “superconductors” R $\rightarrow$ 0 at temperatures below T_c

The current is confined to the surface of the superconductor and acts to shield interior from all external fields. Used to create strong magnetic fields, for example in MRI machines.

New (as of 1986) “high temperature” superconductors –
$T_c \approx 150$ K

Example of a resistor in a circuit:



$$\Delta V = I\,R$$

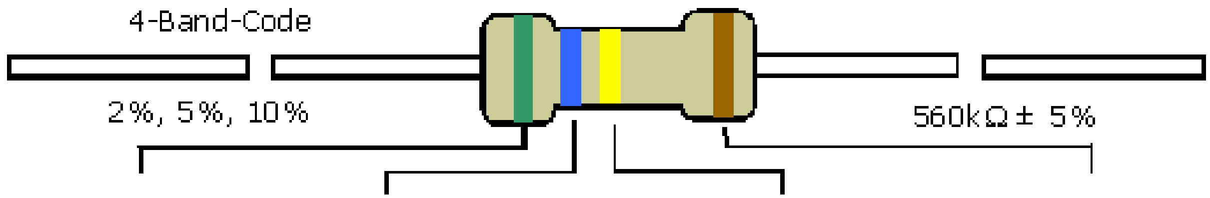
If ΔV = 10 V, R = 20 Ω,

I = 0.5 A

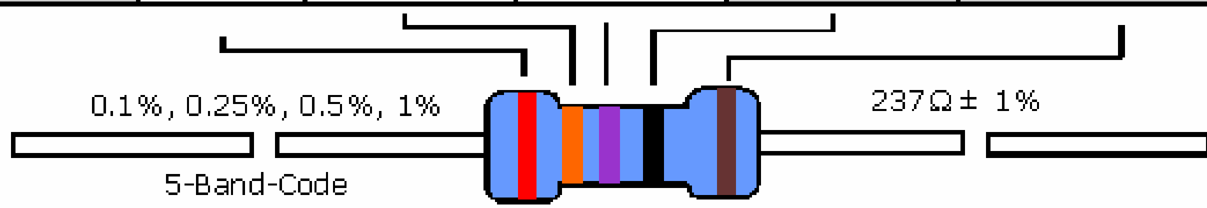
Peer instruction question

In the previous example, we assumed that the 10 V output of the battery is concentrated across the 20 Ω resistor. Are we justified in neglecting the resistance in the wire connecting this circuit? How much error is introduced by this assumption if the wire is made of copper or aluminum?

(A) < 1%   (B) 1%   (C) 10%   (D) >10%



COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)



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4. [HRW6 27.P.026.] In Earth's lower atmosphere there are negative and positive ions, created by radioactive elements in the soil and cosmic rays from space. In a certain region, the atmospheric electric field strength is 110 V/m, directed vertically down. This field causes singly charged positive ions, 690 per cm^3, to drift downward and singly charged negative ions, 580 per cm^3, to drift upward (Fig. 27-24). The measured conductivity is $2.70 \times 10^{-14}/\Omega \cdot m$.

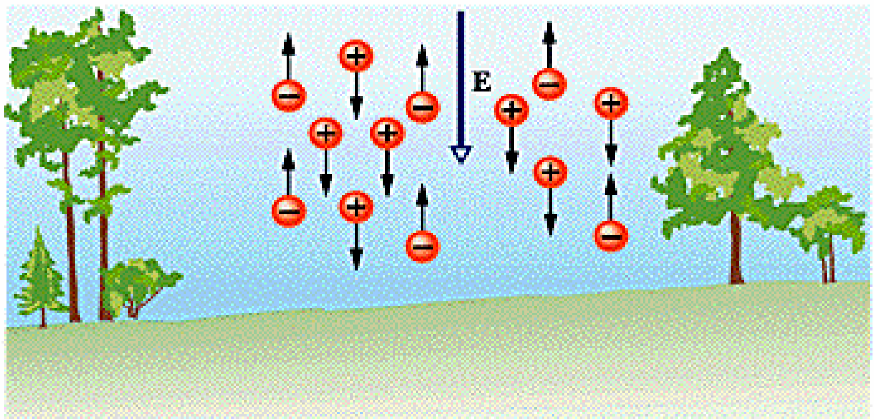


Figure 27-24.

Calculate

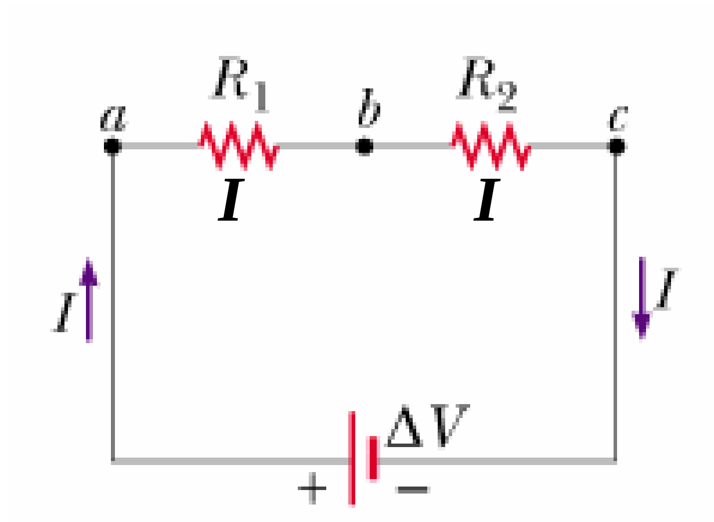
(a) the ion drift speed, assumed to be the same for positive and negative ions, and

[ ] cm/s

(b) the current density.

[ ] A/m^2

Connecting resistors in series:



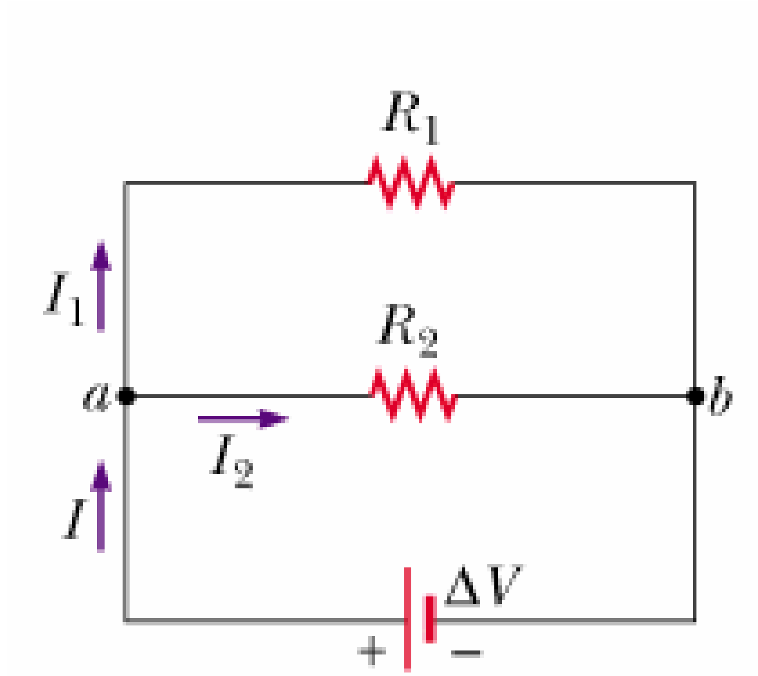
The same current I passes through both resistors R_1 and R_2.

$$\Delta V = I\,R_1 + I\,R_2$$
$$= I\,(R_1 + R_2)$$

➔For resistors connected in series:

$$R_{eq} = \sum_i R_i$$

Resistors connect in parallel



The same voltage ΔV passes through each resistor:

$\Delta V = I_1 R_1 = I_2 R_2$

➔For resistors connected in parallel:

$$\frac{1}{R_{eq}} = \sum_i \frac{1}{R_i}$$