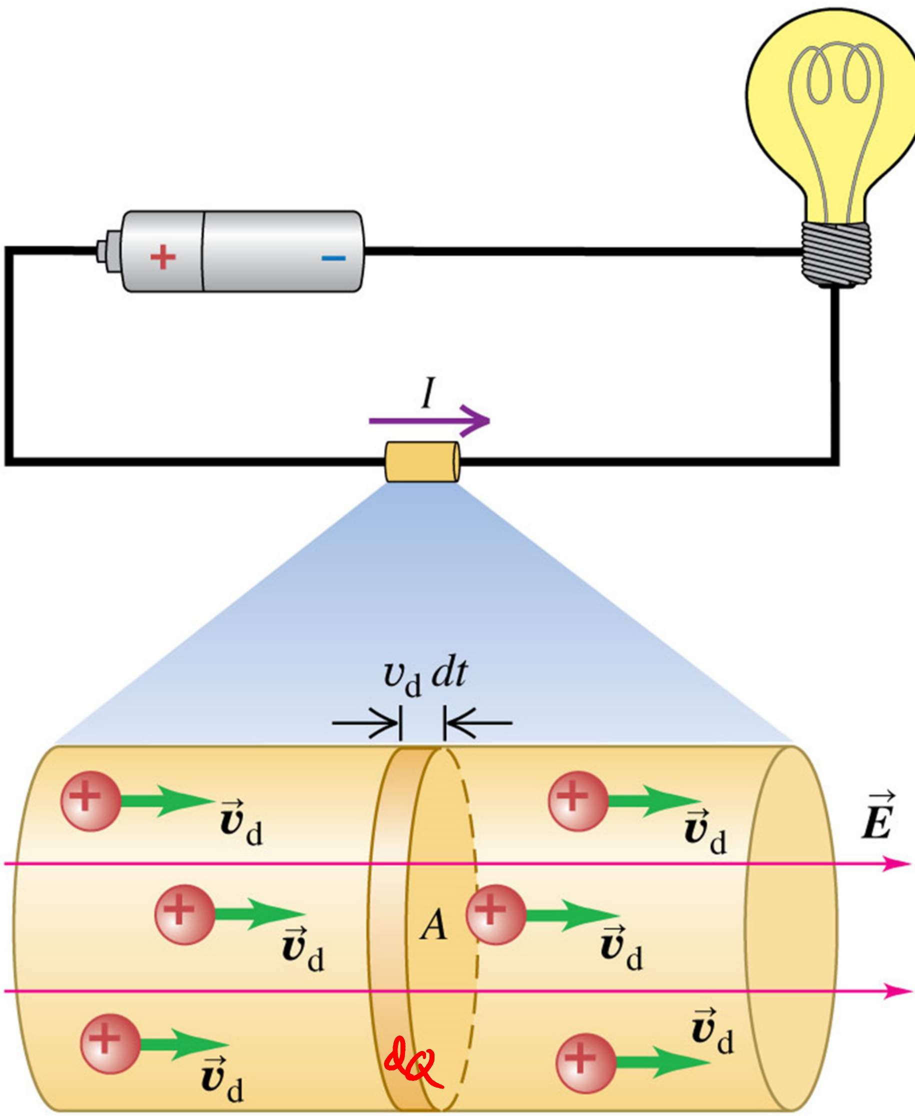


Current $I = \dfrac{dQ}{dt}$

$\vec{F} = q\vec{E} = ma \qquad \vec{a} = \dfrac{-e\vec{E}}{m_e}$

Over Δt, a makes $\vec{v}_d = \vec{a}\,\Delta t$

$$v_d = \frac{e\vec{E}\,\Delta t}{m_e}$$

$n \quad \dfrac{\text{charges}}{m^3}$

each charge moves $(v_d\,dt)$ in dt

Volume $(A\,v_d\,dt)$ contains $n\,(A\,v_d\,dt)$

$$dQ = q\,n\,(v_d\,dt\,A)$$

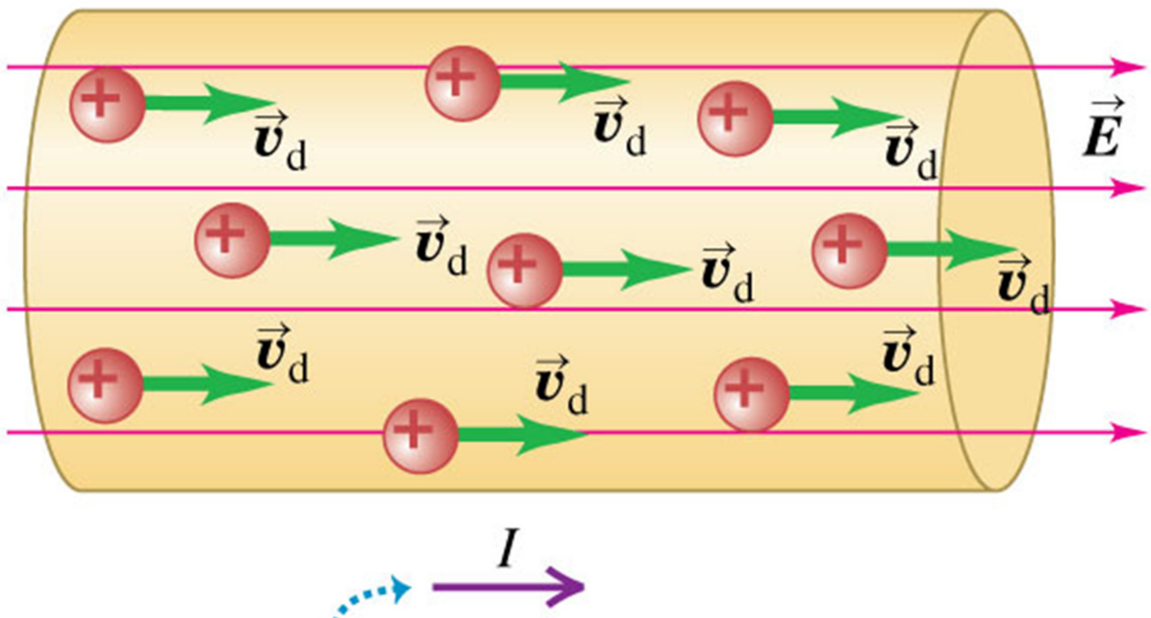
$$\frac{dQ}{dt} = q\,n\,v_d\,A = I$$

define J = current density

$$J = I/A = q\,n\,v_d$$

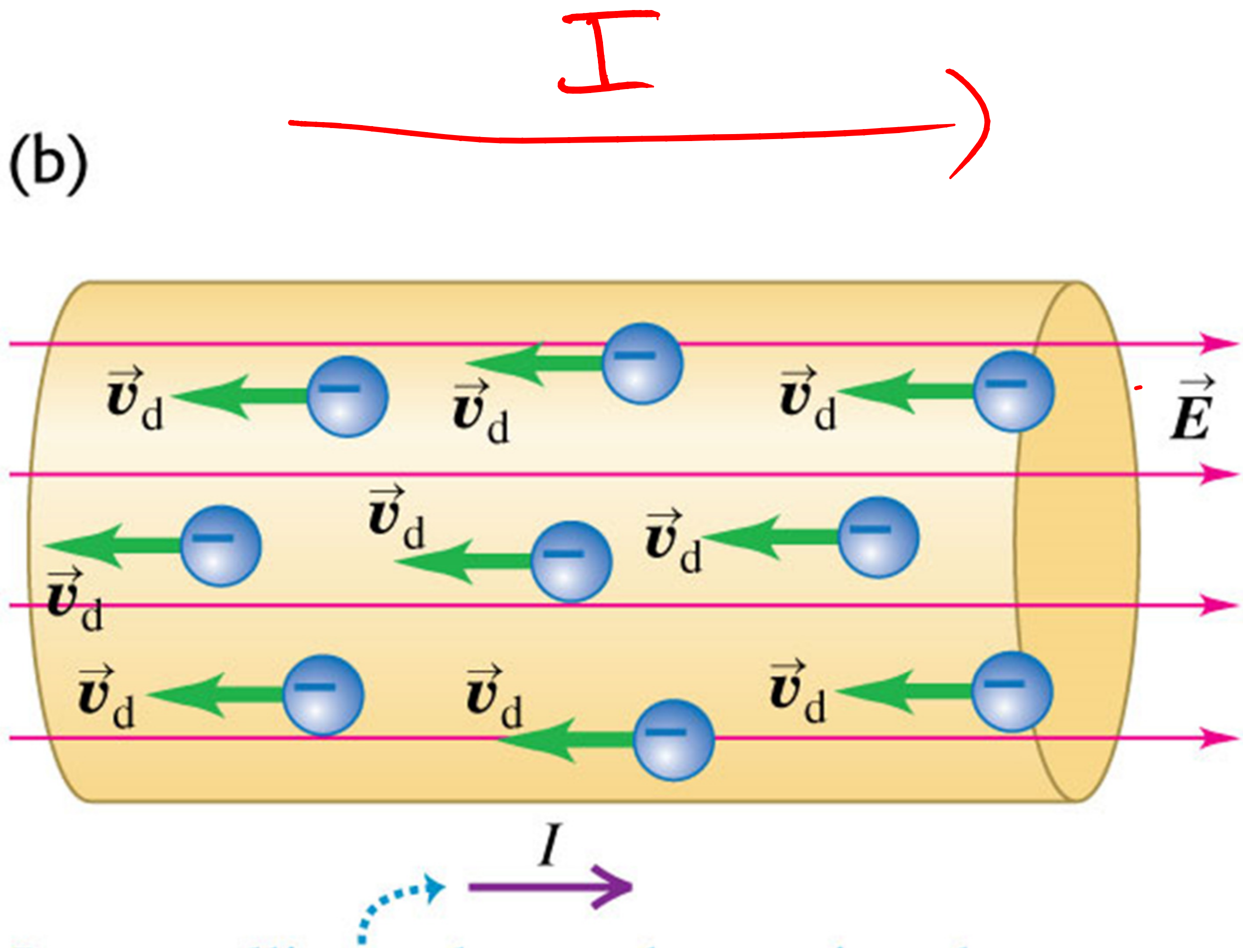
$I \longrightarrow$ (flow of positive charge)

(a)



A **conventional current** is treated as a flow of positive charges, regardless of whether the free charges in the conductor are positive, negative, or both.

(b)



In a metallic conductor, the moving charges are electrons — but the *current* still points in the direction positive charges would flow.

Resistivity

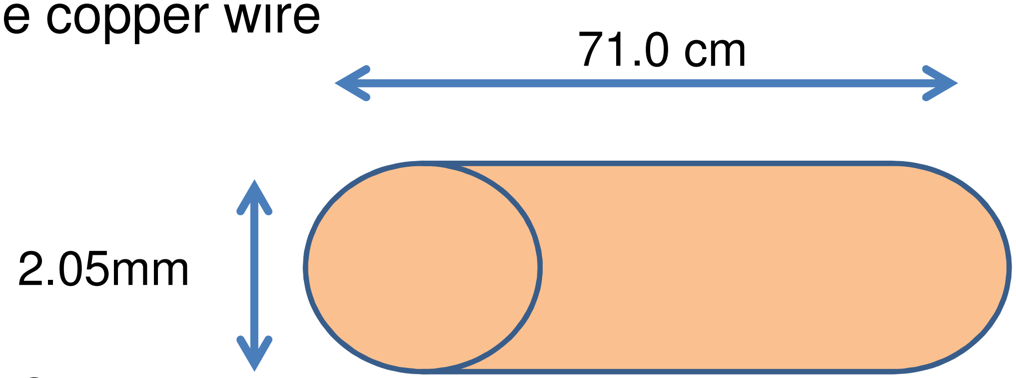
define $\vec{J}$ = current density = I/A

$= q n v_d$

$\frac{\text{amps}}{m^2}$ $\vec{E} = \vec{J}\rho$

ρ = resistivity $\vec{E}/\vec{J}$ $\frac{V/m}{A/m^2} = V/A \cdot m$

I=4.85A goes through this 12 gauge copper wire



There are $8.5x10^{28}$
conduction electrons per m^3 in Cu

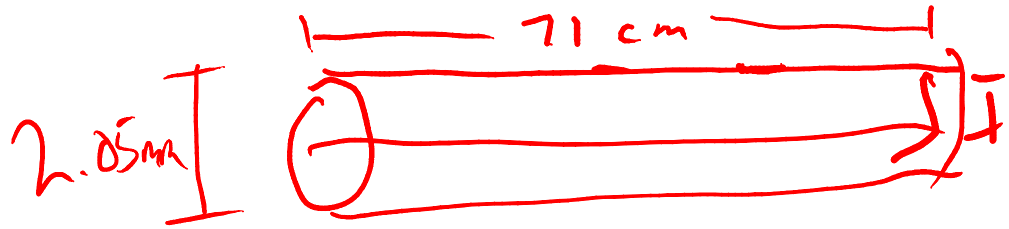
a) How long does it take one
electron to go down this whole wire?

b) What if you used 6 gauge (4.12mm diameter) wire instead?

c) Given what you've figured out just now, why do lights come on as soon as you flip the switch?

d) Cu has a density of 8.96 g/cm^3 and an atomic mass of 63.55 g/mole
How many electrons are available for conduction per atom?

$I = 4.85A$



need v_d. know $\vec{J} = nq\vec{v}_d$

also know $J = I/A$ so $I/A = nqv_d$

$\therefore v_d = \frac{I}{Anq} = \frac{I}{\pi (d/2)^2 nq}$ q? one electronic charge

$$v_d = \frac{4.85A \cdot 4}{\pi(2.05\times10^{-3}m)^2(8.5\times10^{28}\,e's/m^3)(1.6\times10^{-19}C)} = 1.08\times10^{-4}\,m/s$$

So. $t = L/v_d = \frac{0.710\,m}{1.08\times10^{-4}\,m/s} = 6.58\times10^{3}\,s$ or 110 m

b) if $d = 4.12$ mm, that's 2x old d

so $v_d \propto \frac{1}{d^2}$ or $v_d = \frac{1}{4}$ old v_d

so t = 4x longer, or 440 m

While any one charge takes forever,

the "hose" is full of them, so the ones near the

end comes out right away.

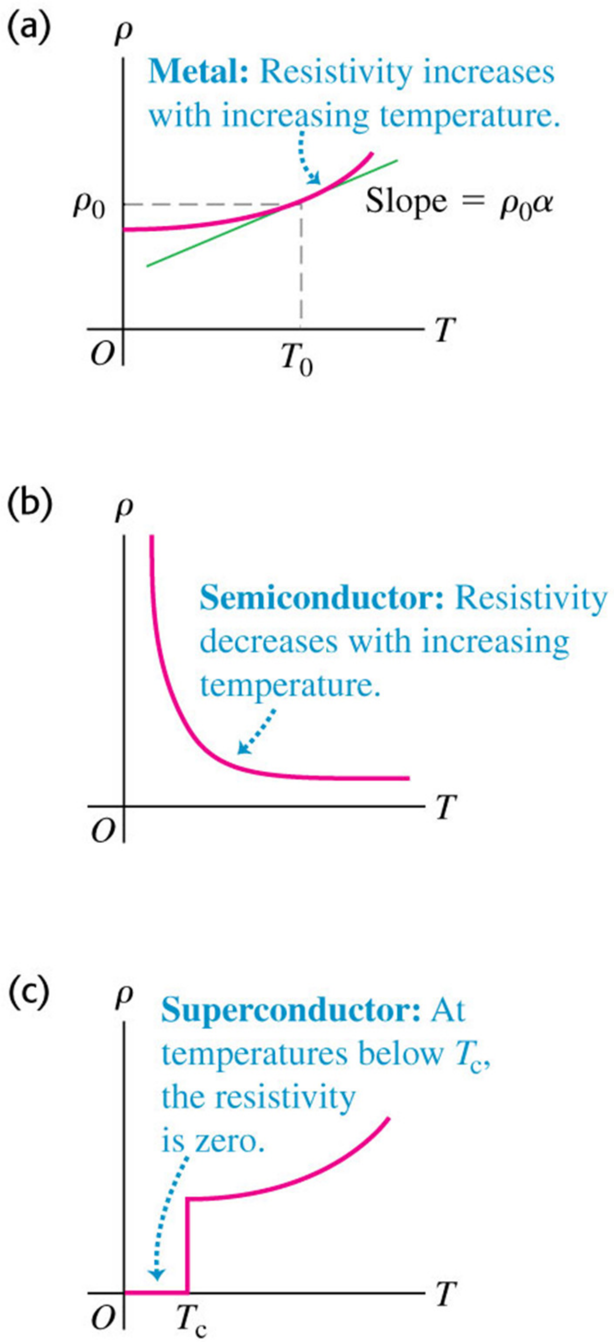
need $\frac{\text{atoms}}{m^3}$

so $$\frac{8.96 \frac{g}{cm^3} \cdot \left(1.00\times10^6 \frac{cm^3}{m^3}\right)\left(6.022\times10^{23} \frac{\text{atoms}}{\text{mole}}\right)}{63.55\ g/\text{mole}}$$

$$= 8.49\times10^{28} \frac{\text{atoms}}{m^3}$$

same as # of free electrons/m3!

so, one free e per Cu atom

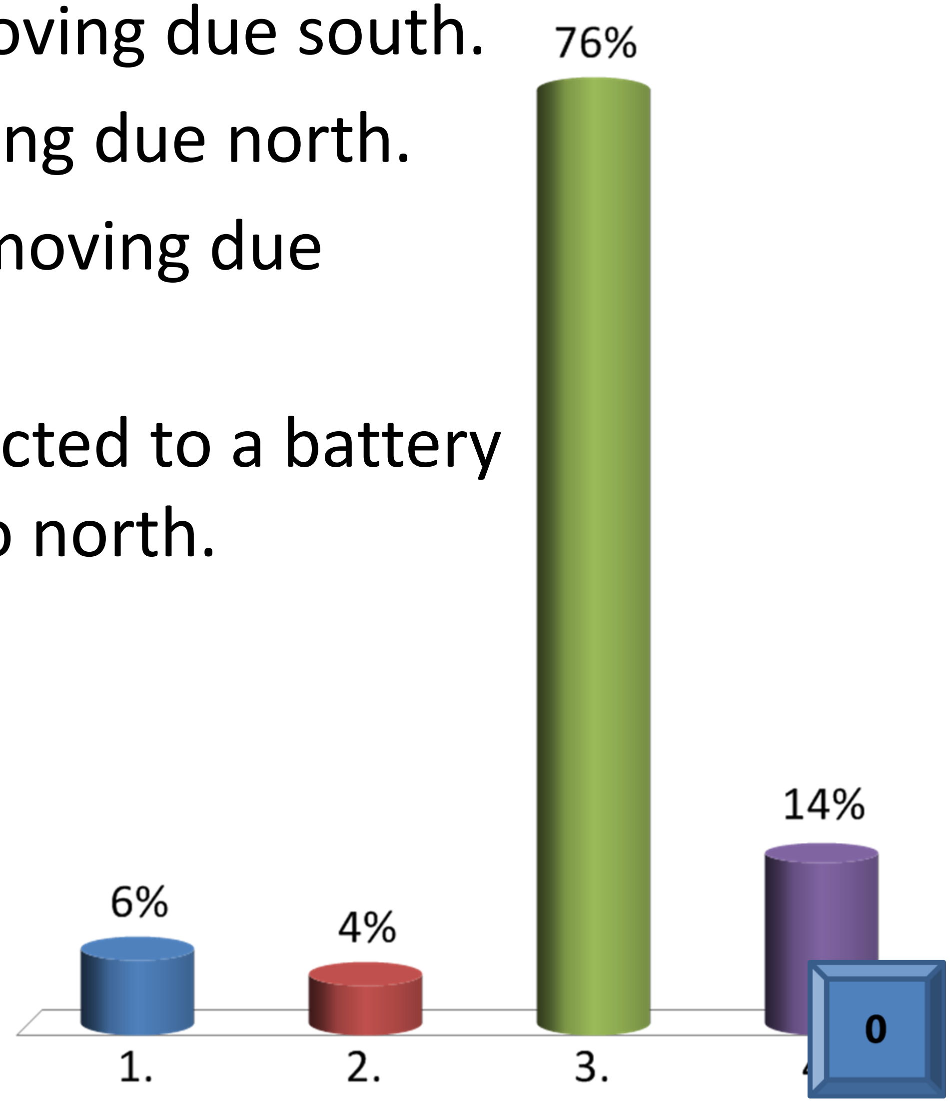


$$\rho(T) = \rho_0\left[1 + \alpha(T - T_0)\right]$$

$$\vec{E} = \vec{J}\rho$$

In which one of the following situations does a conventional electric current flow due north?

1. Protons in a beam are moving due south.
2. A water molecule is moving due north.
3. Electrons in a beam are moving due south.
4. Electrons in a wire connected to a battery are moving from south to north.



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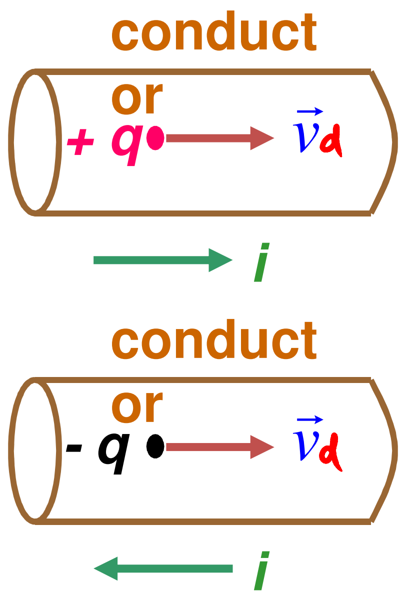
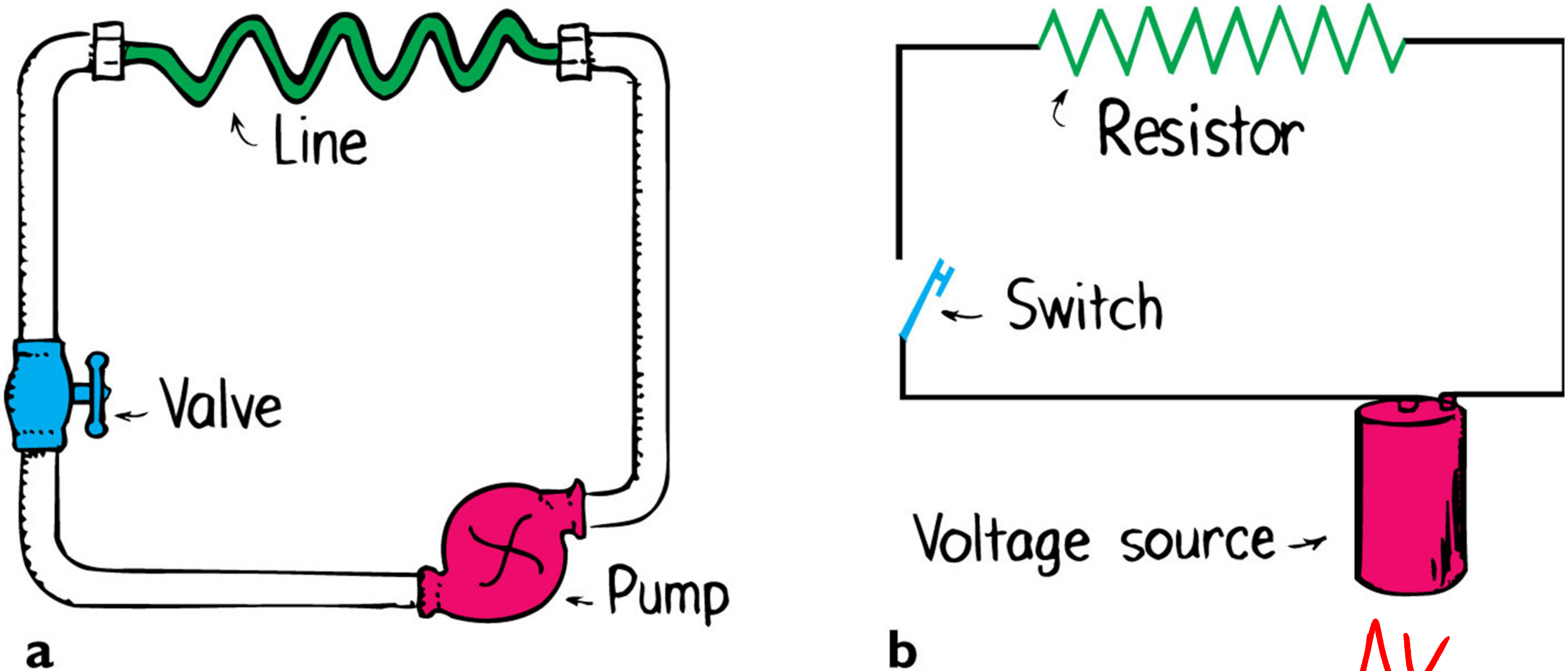
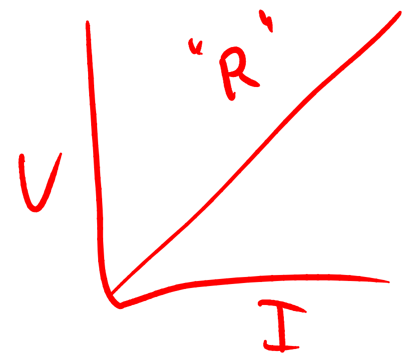

conduct
or
+ q
$\vec{v}_d$
i
conduct
or
- q
$\vec{v}_d$
i

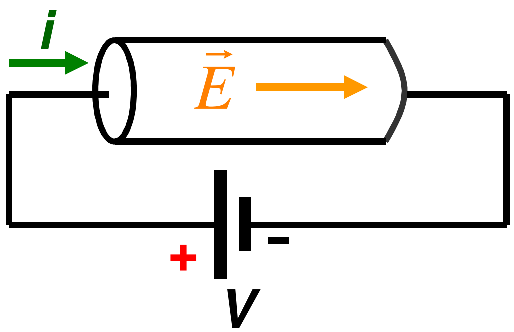


ΔV

$R = V/I = V/A = \text{ohm} \quad \Omega$

$V = IR$ Ohm's Law

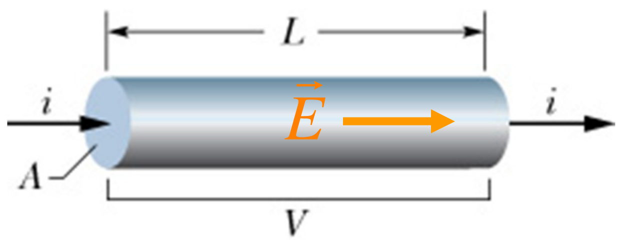




$\vec{E} = \rho \vec{J}$

$\vec{J} = \sigma \vec{E}$

$\sigma = 1/\rho$



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

How do you figure out R for some chunk of stuff?

$R = V/I \quad (\Omega)$

$$\rho = \frac{|\vec{E}|}{|\vec{J}|} = \frac{V/m}{A/m^2} = \frac{V}{A} \cdot m = \Omega \cdot m$$

$E = V/L \qquad J = I/A$

$$R = V/I \qquad \rho = E/J = \frac{V/L}{I/A} = \frac{V A}{I L} \rightarrow R$$

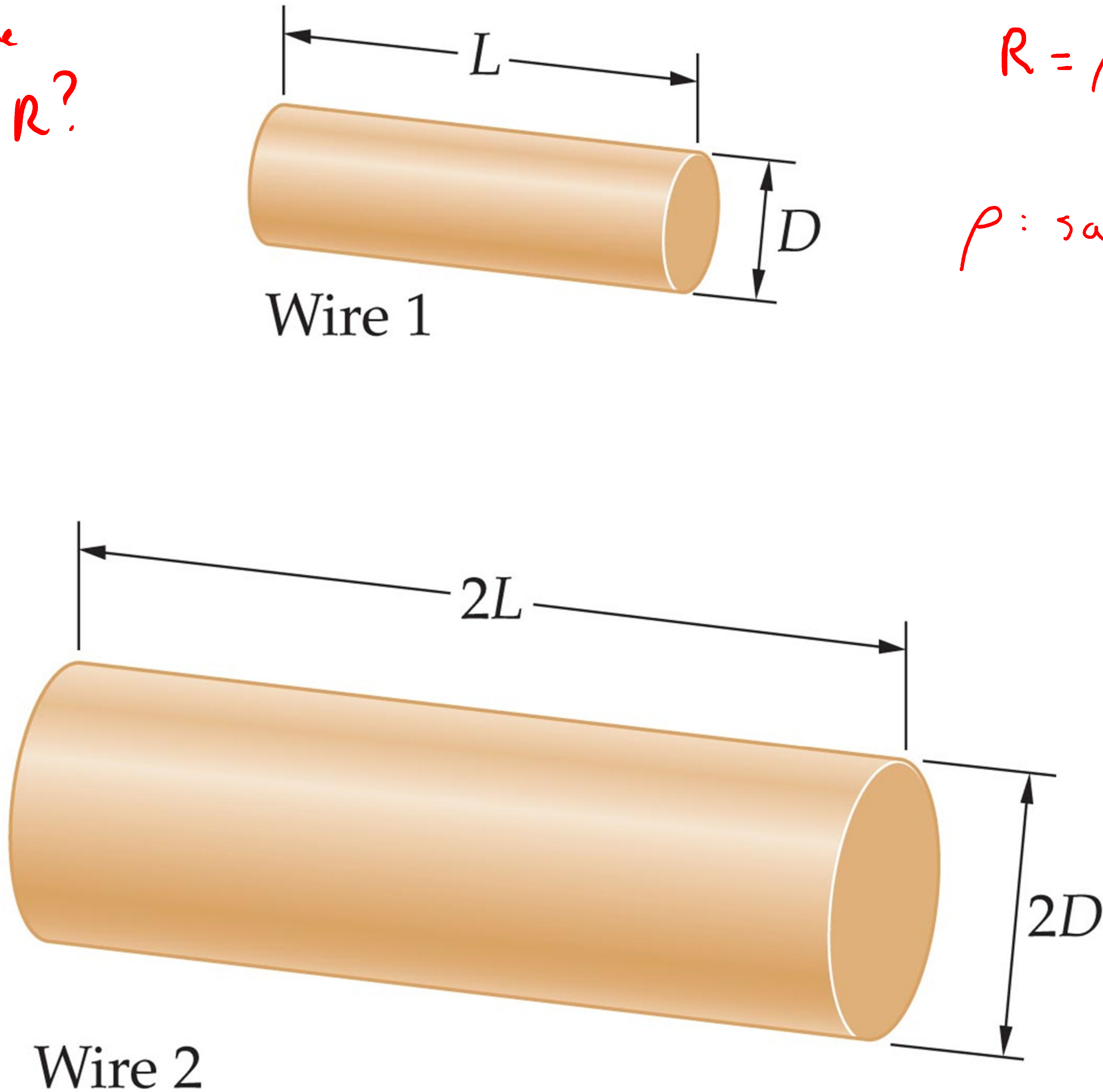
$$\rho = R \cdot A/L$$

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

Which one has more R?

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

ρ : same stuff



The ends of a wire are connected to the terminals of a battery. For which of the following changes will the resulting current in the circuit have the largest value?

1. Replace the wire with one that has a larger resistivity.
2. ✔ Replace the wire with one that has a larger radius.
3. Replace the wire with one that has a longer length.

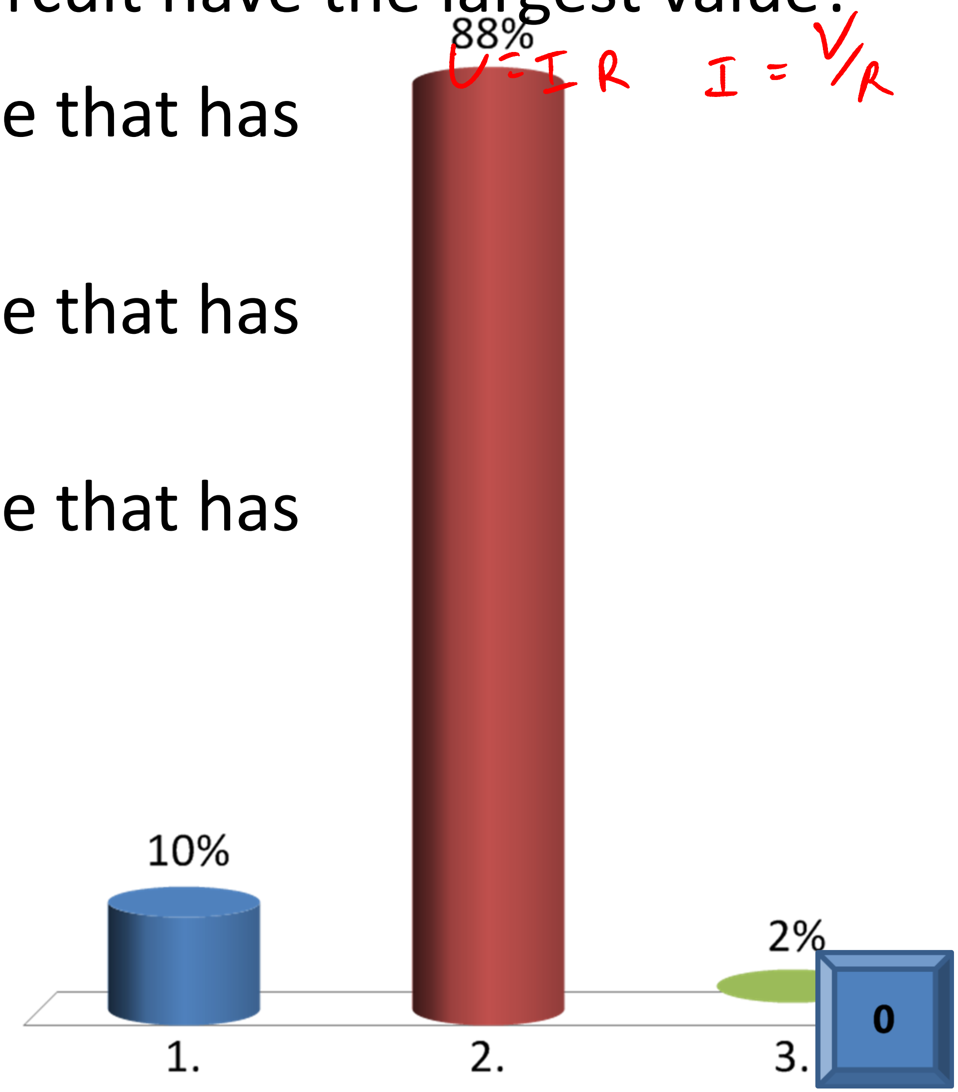


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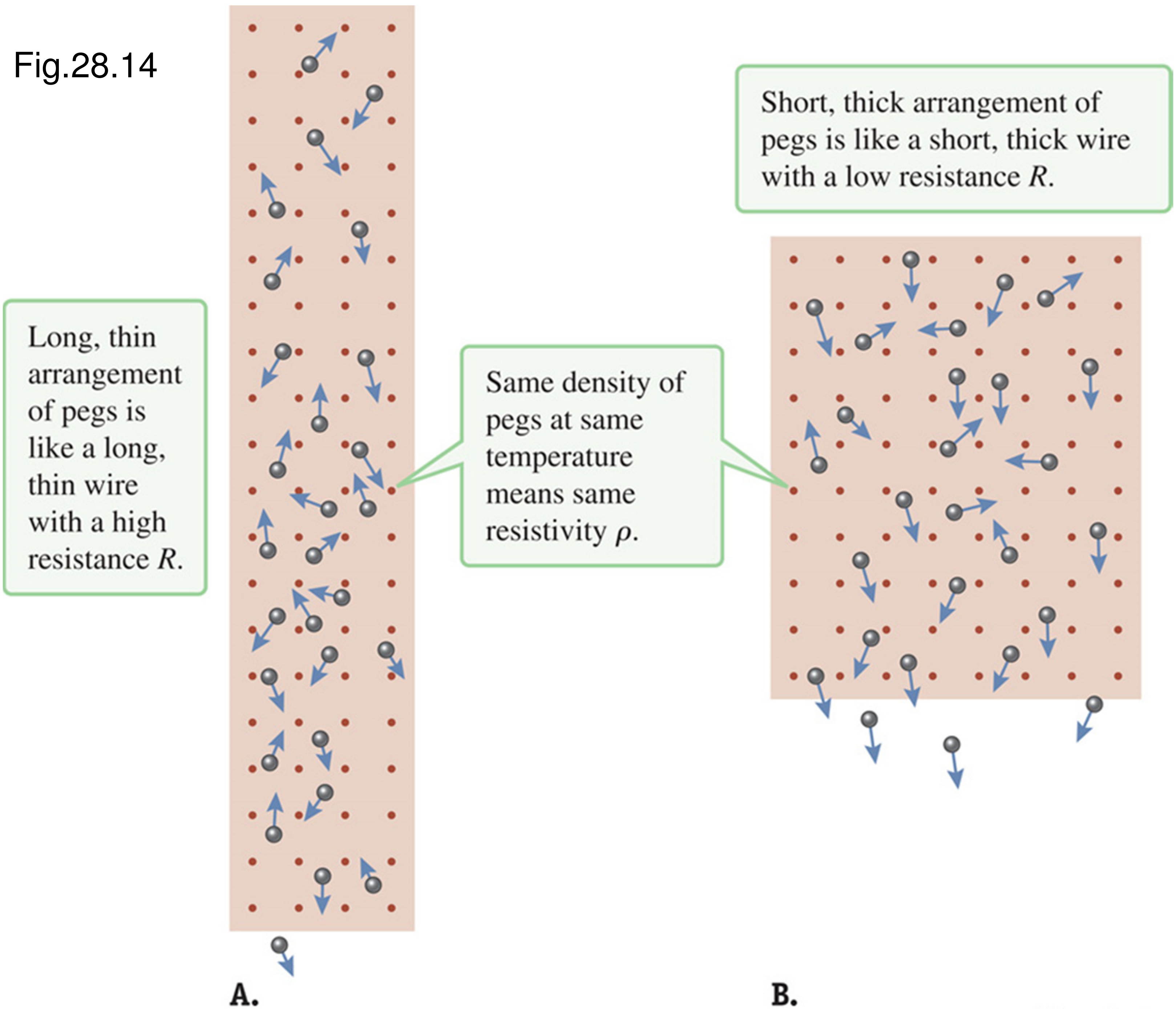
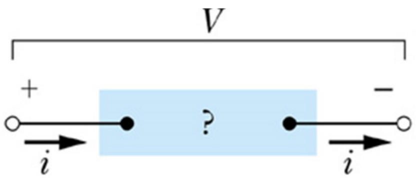
Fig.28.14



Long, thin arrangement of pegs is like a long, thin wire with a high resistance *R*.
Same density of pegs at same temperature means same resistivity *ρ*.
Short, thick arrangement of pegs is like a short, thick wire with a low resistance *R*.
A.
B.

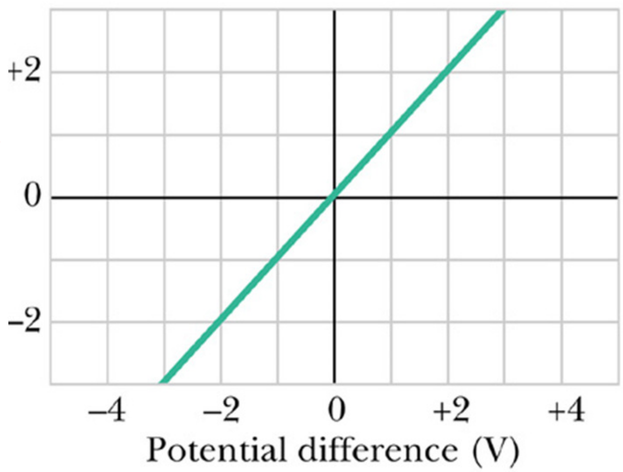


(a)

$$V = IR$$

Ohmic things obey Ohm's Law

$$V = RI$$



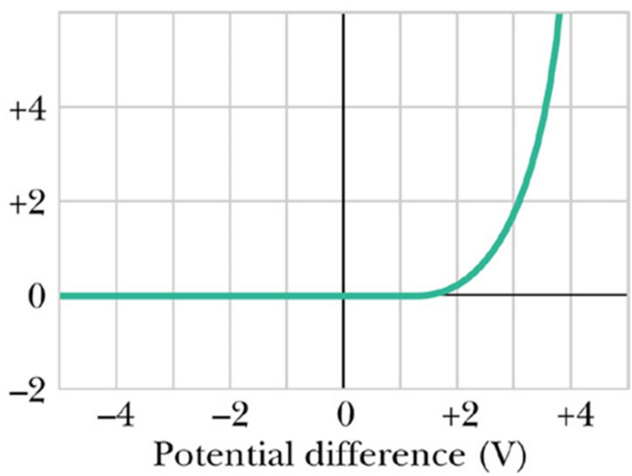
I

(b)

Resistor $\Delta V = 1V$

$\Delta A = 1A$

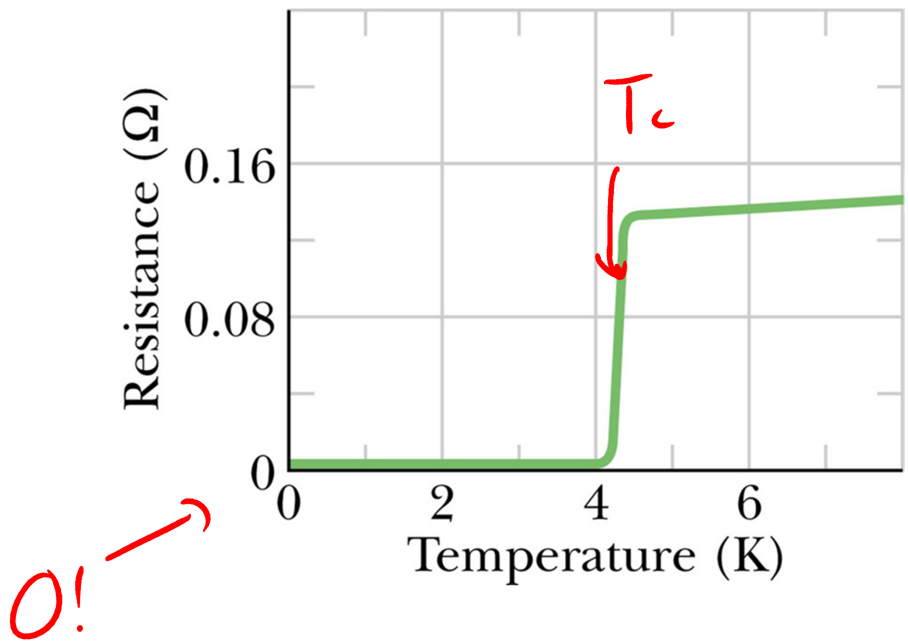
$R = 1\Omega$

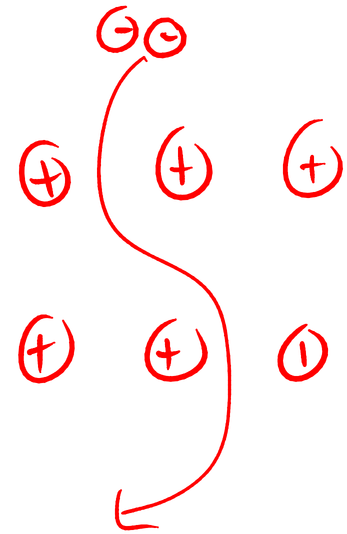


I

(c)

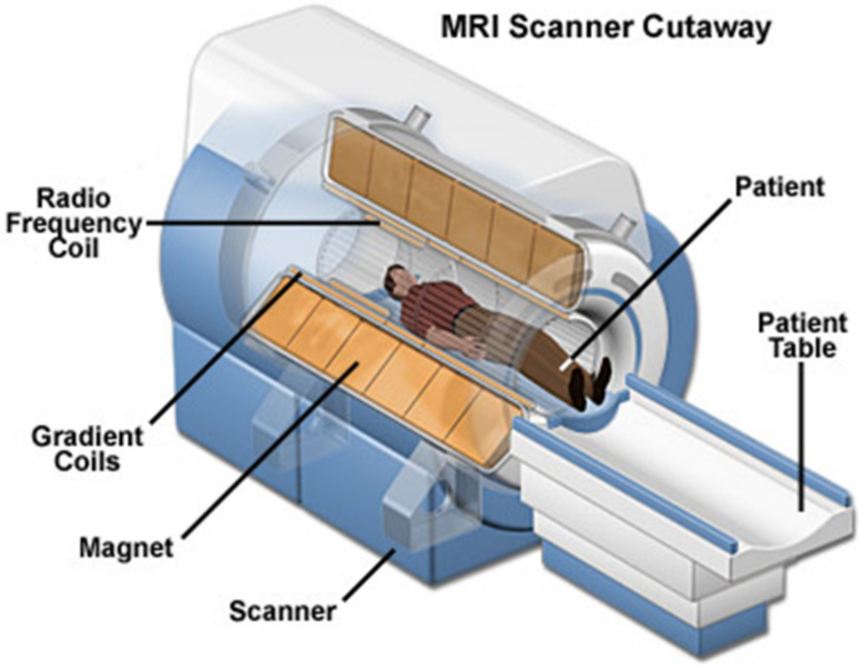
Diode

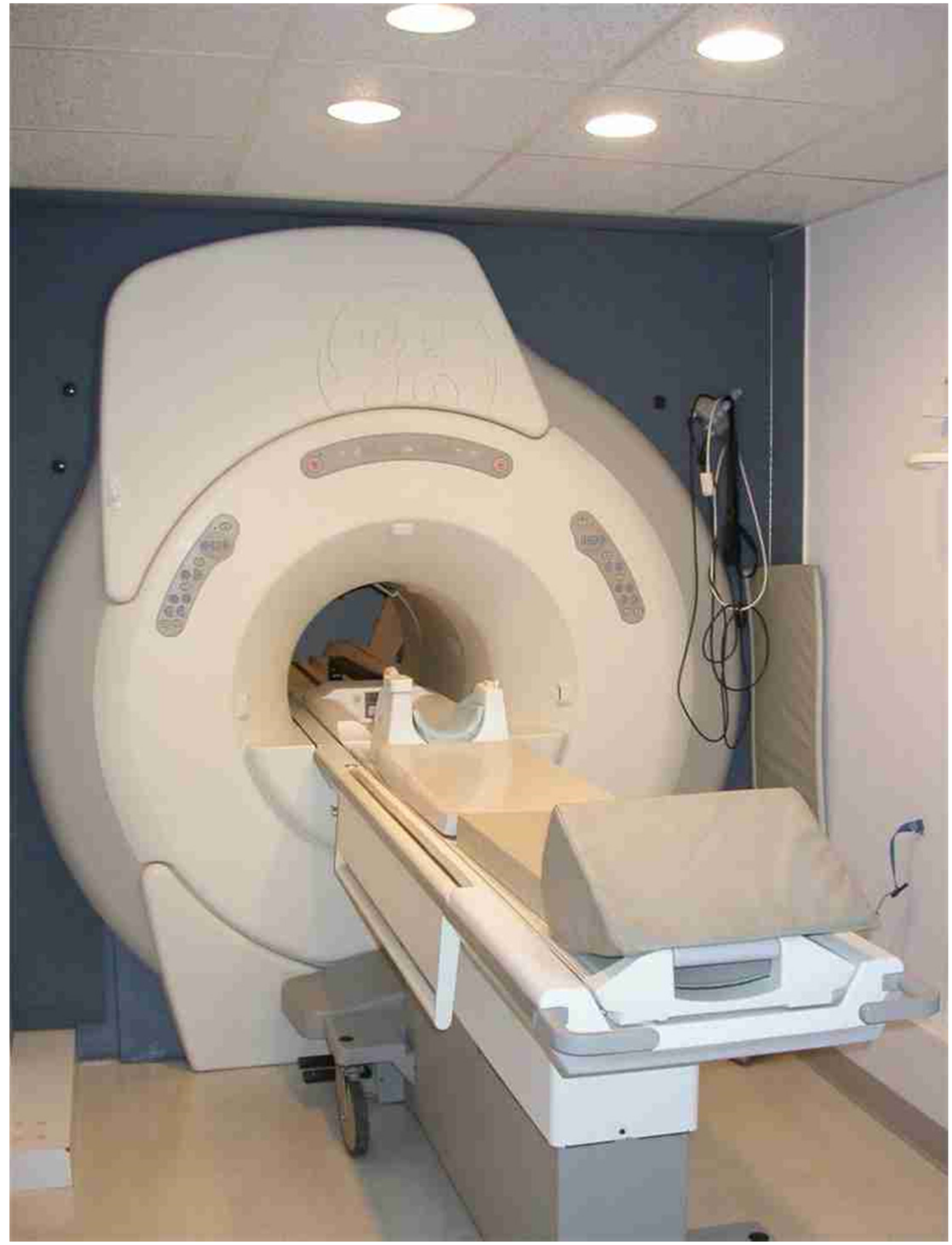


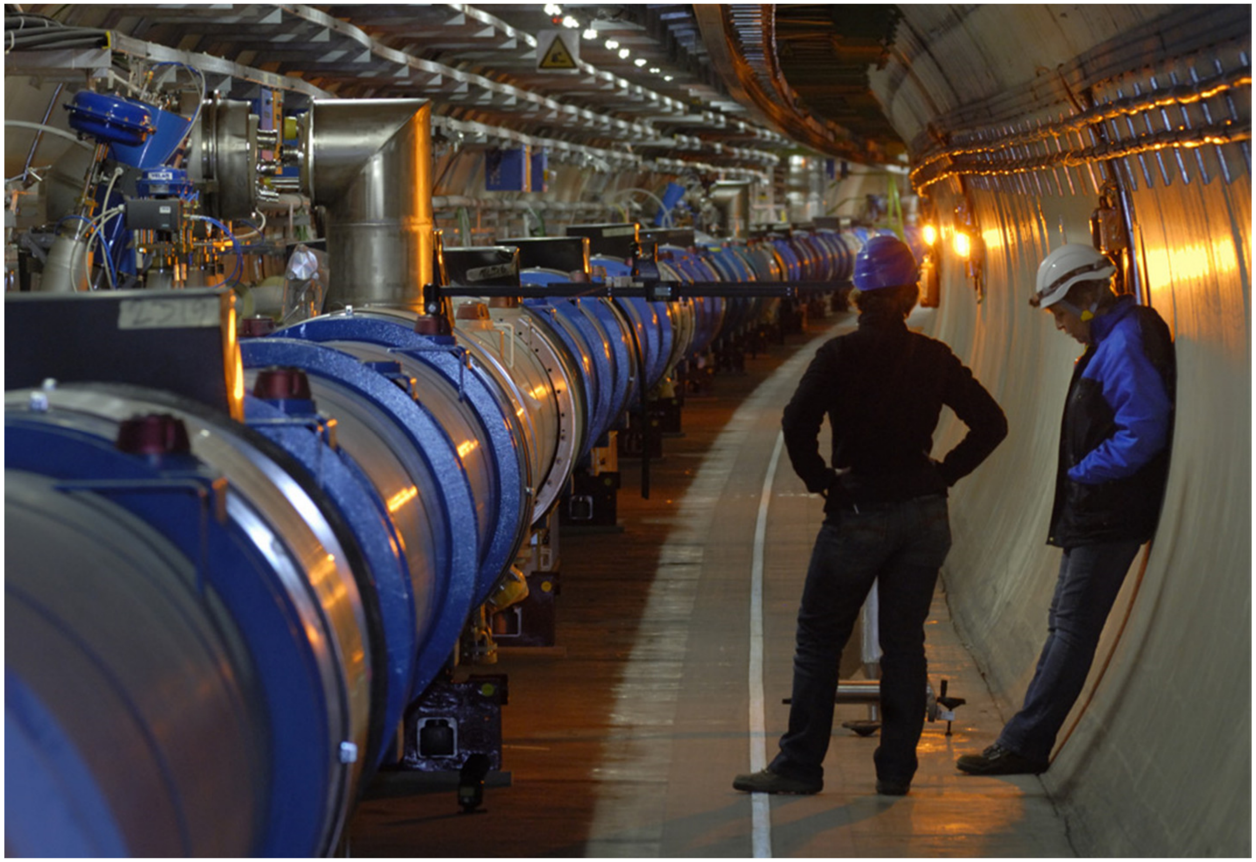


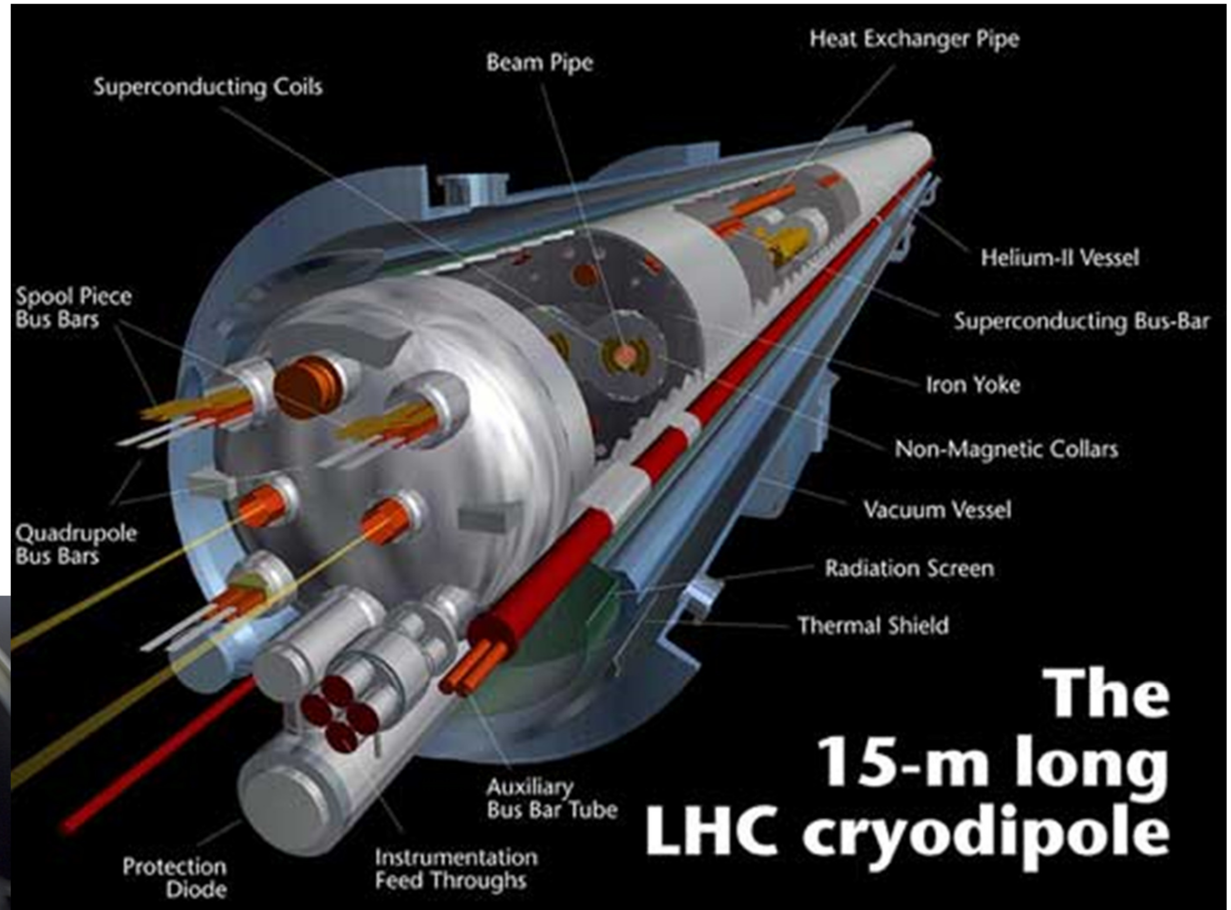
Superconductors

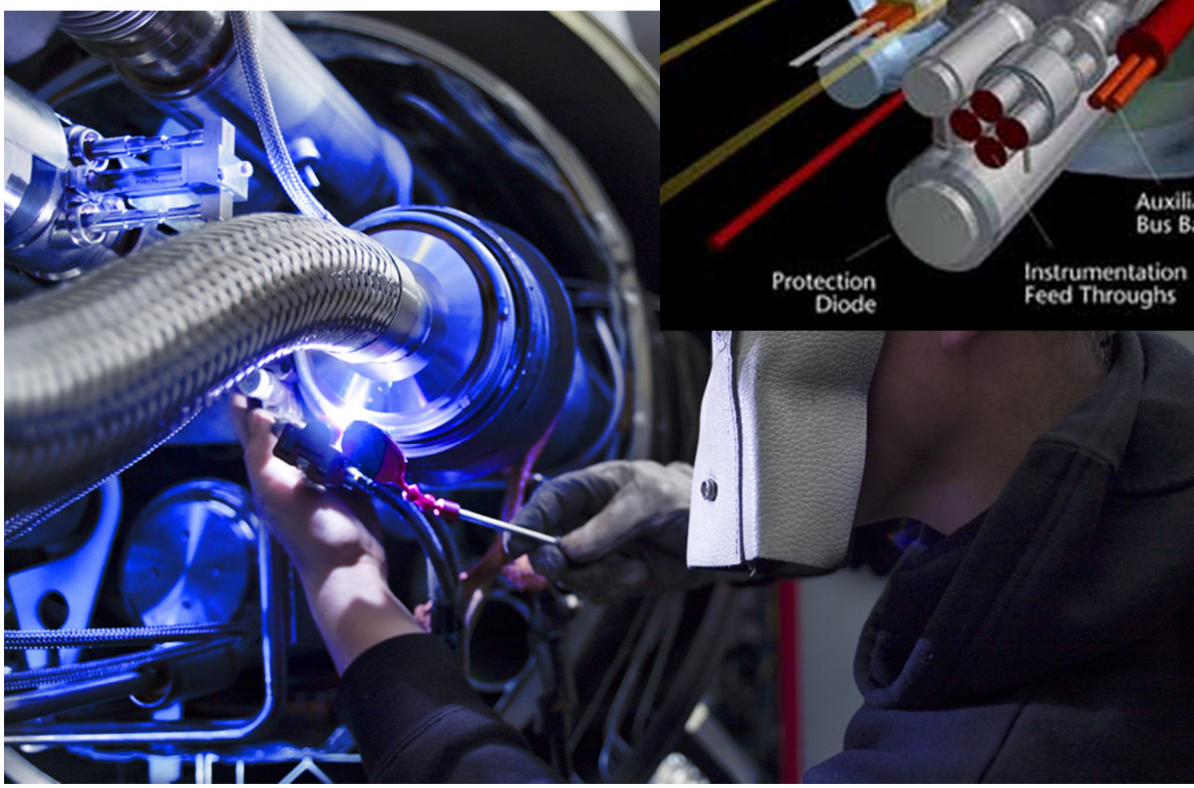
$R \to 0$ as $T \to 0$

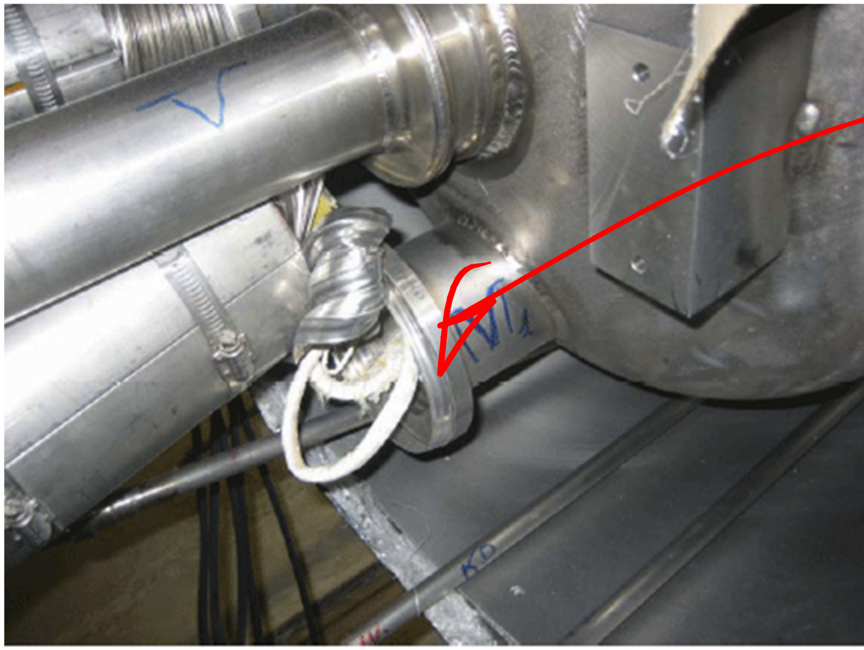

MRI Scanner Cutaway
Radio Frequency Coil
Patient
Patient Table
Gradient Coils
Magnet
Scanner






Heat Exchanger Pipe
Beam Pipe
Superconducting Coils
Helium-II Vessel
Spool Piece
Bus Bars
Superconducting Bus-Bar
Iron Yoke
Non-Magnetic Collars
Vacuum Vessel
Quadrupole
Bus Bars
Radiation Screen
Thermal Shield
The
15-m long
LHC cryodipole
Auxiliary
Bus Bar Tube
Protection
Diode
Instrumentation
Feed Throughs

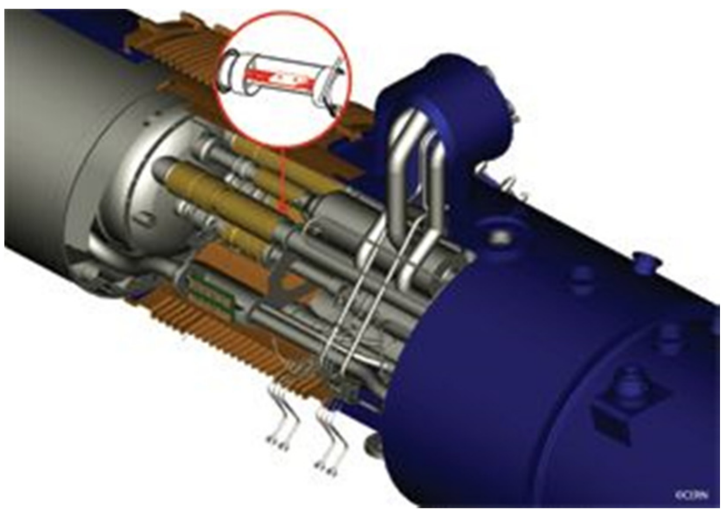




"R" from a cold solder

$I^2 \cdot R \to$ heat

Quench

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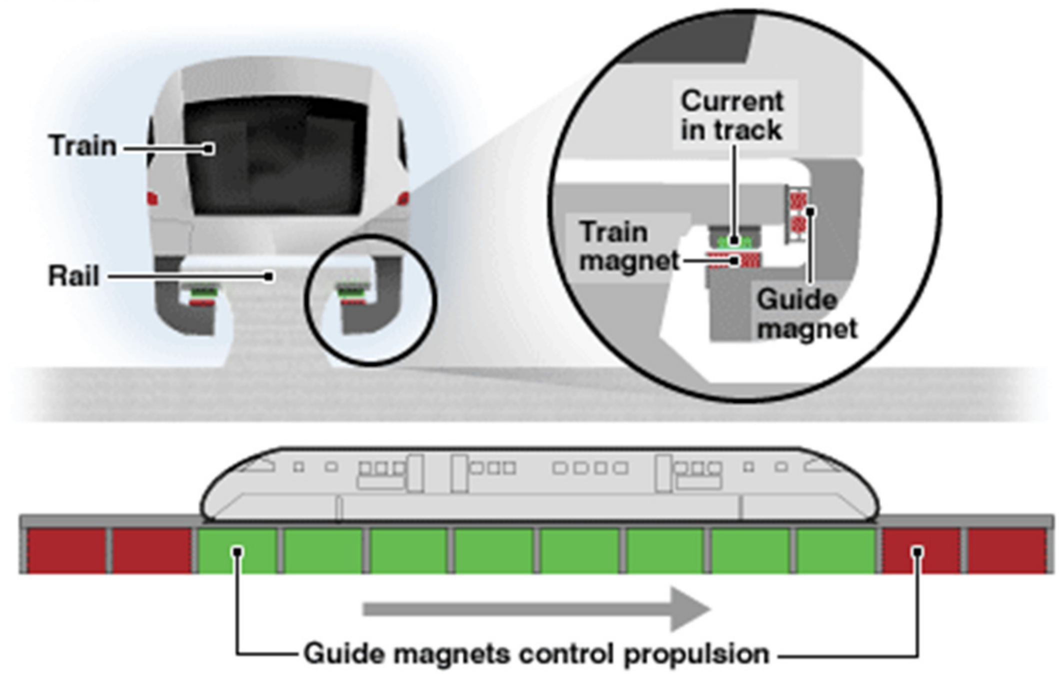

Train
Rail
Current in track
Train magnet
Guide magnet
Guide magnets control propulsion

A Resistivity Problem

from the table, Tungsten has $\rho_{20} = 5.25 \times 10^{-8}\ \Omega m$

$\alpha = 0.0045 / C$

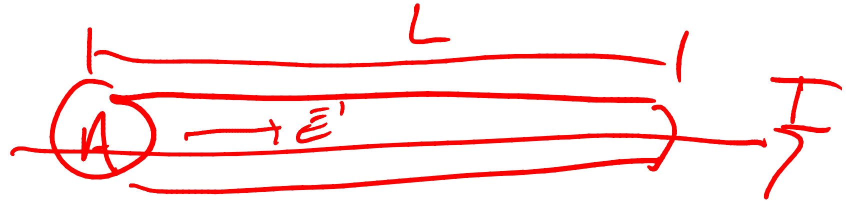
$E = \rho J \qquad J = I/A \qquad \rho = \rho_{20}\left(1 + \alpha (T - T_{20})\right)$

so $E = \rho_{20}\left(1 + \alpha(T - T_0)\right) \dfrac{I}{A}$ $\qquad A = \pi \left(\dfrac{1.0 \times 10^{-3} m}{2}\right)^2$

so $E = 1.21\ V/m$ $\qquad \rho(20C) = 7.61 \times 10^{-8}\ \Omega m$

why @ 120? Hotter, more ρ, more ρ more E

from $E = \rho J$



What's R (120 C)?

$$R = \frac{\rho_{120} L}{A} = \frac{(7.61 \times 10^{-8}\,\Omega\cdot m)\cdot(0.15\,m)}{\pi\,(0.005\,m)^2}$$

$$= 0.0145\,\Omega$$

Small! even a not-so-good conductor like Tungsten still conducts pretty well

What's ΔV?

$$V = I R = (12.5 A)(0.0145 \Omega) = 0.182 V$$