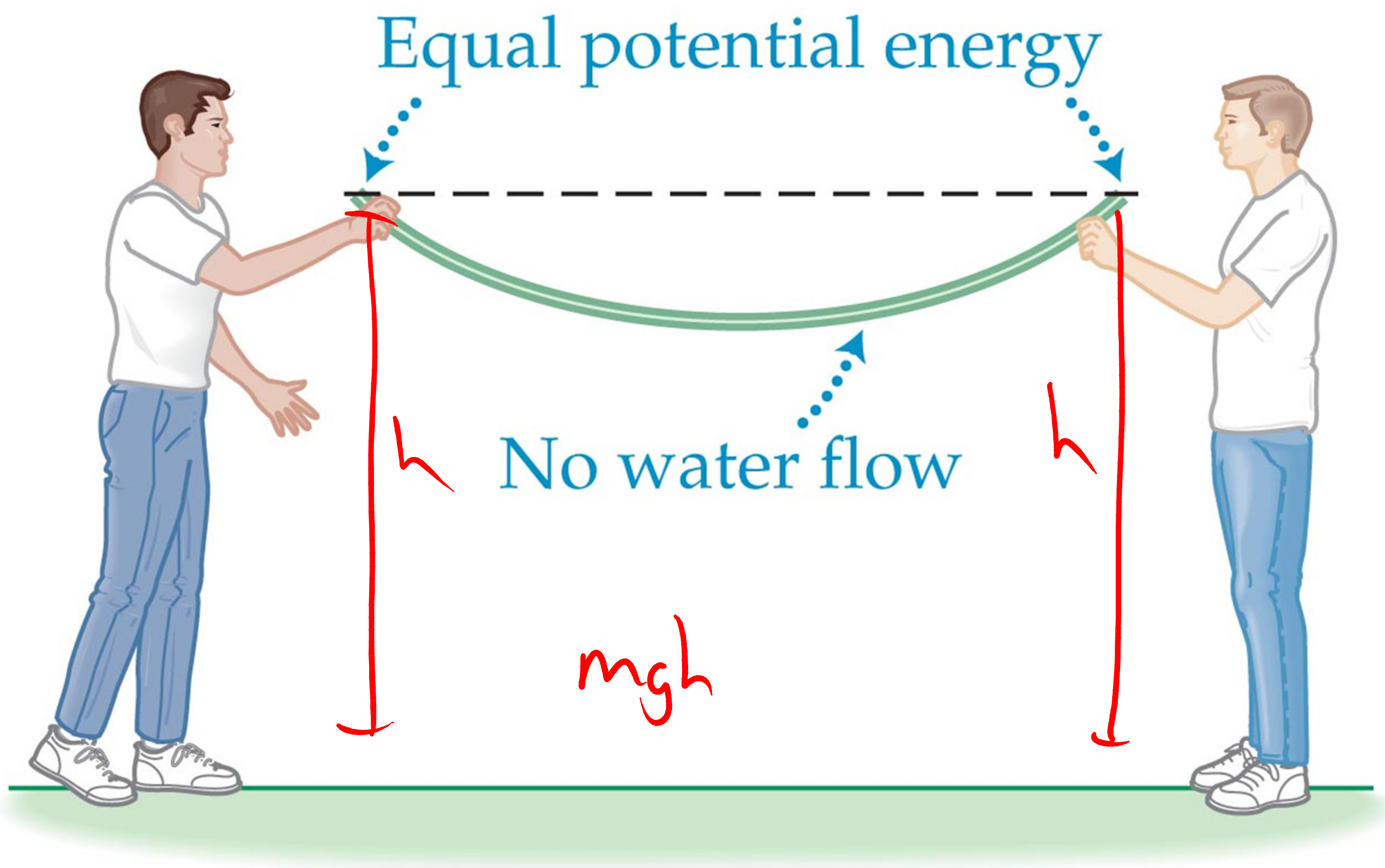
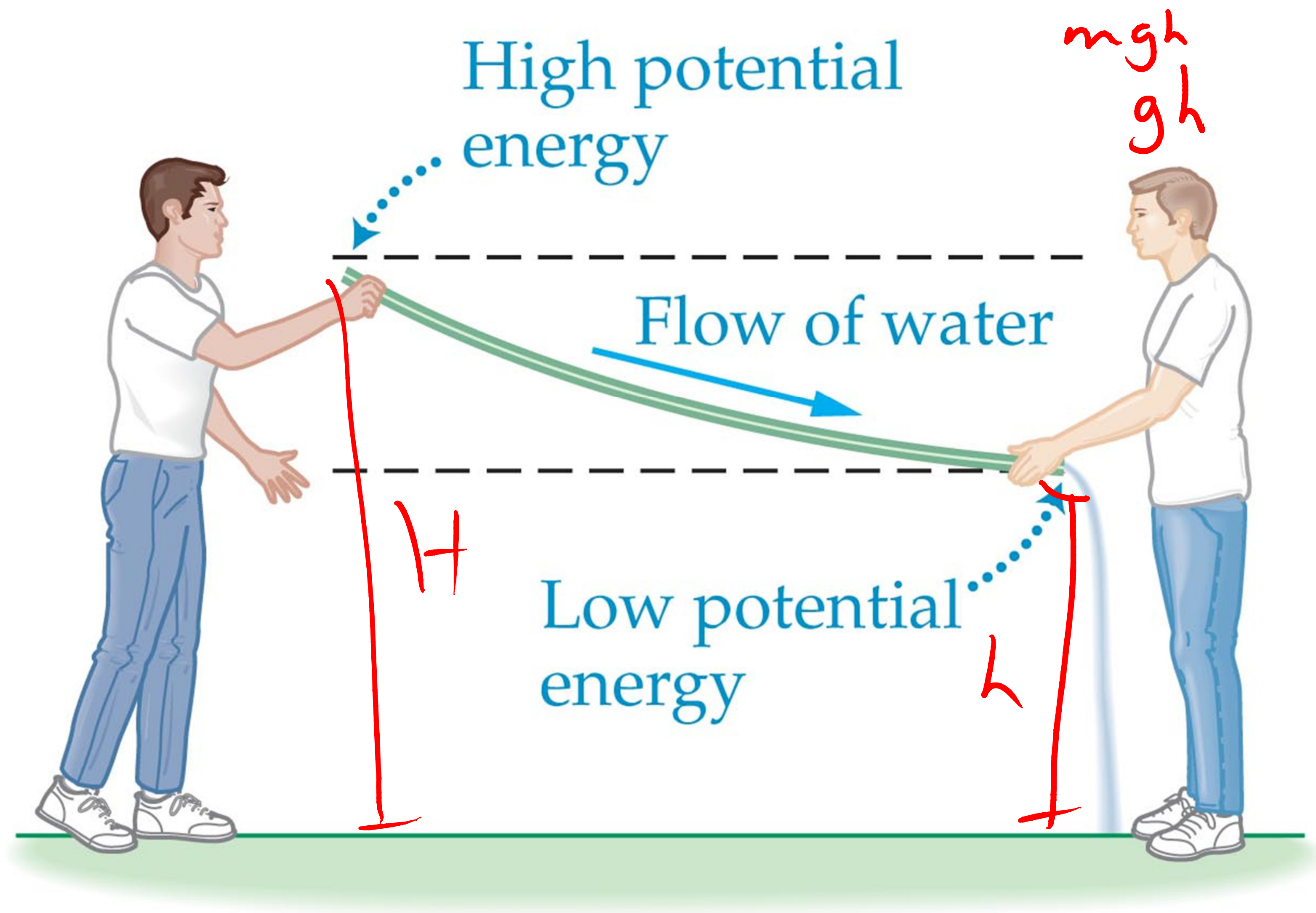
Test Wednesday

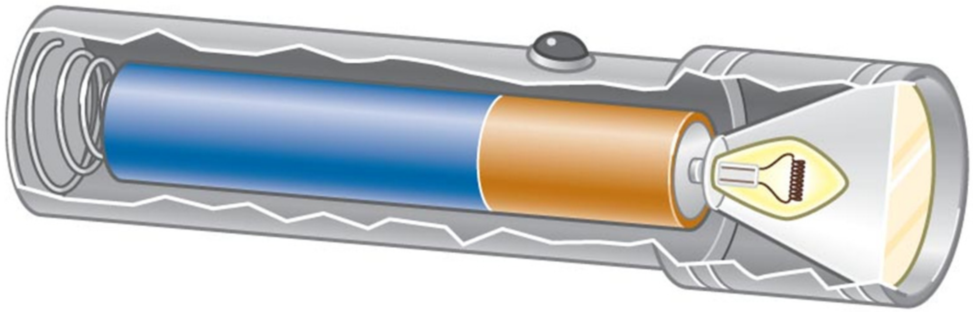
- Chapters 27, 28, 29
- Same format as last time
  - Example test has been posted for weeks: try taking it as a practice test before looking at the answers!
- Again, you can bring a sheet of paper with whatever you want written on it



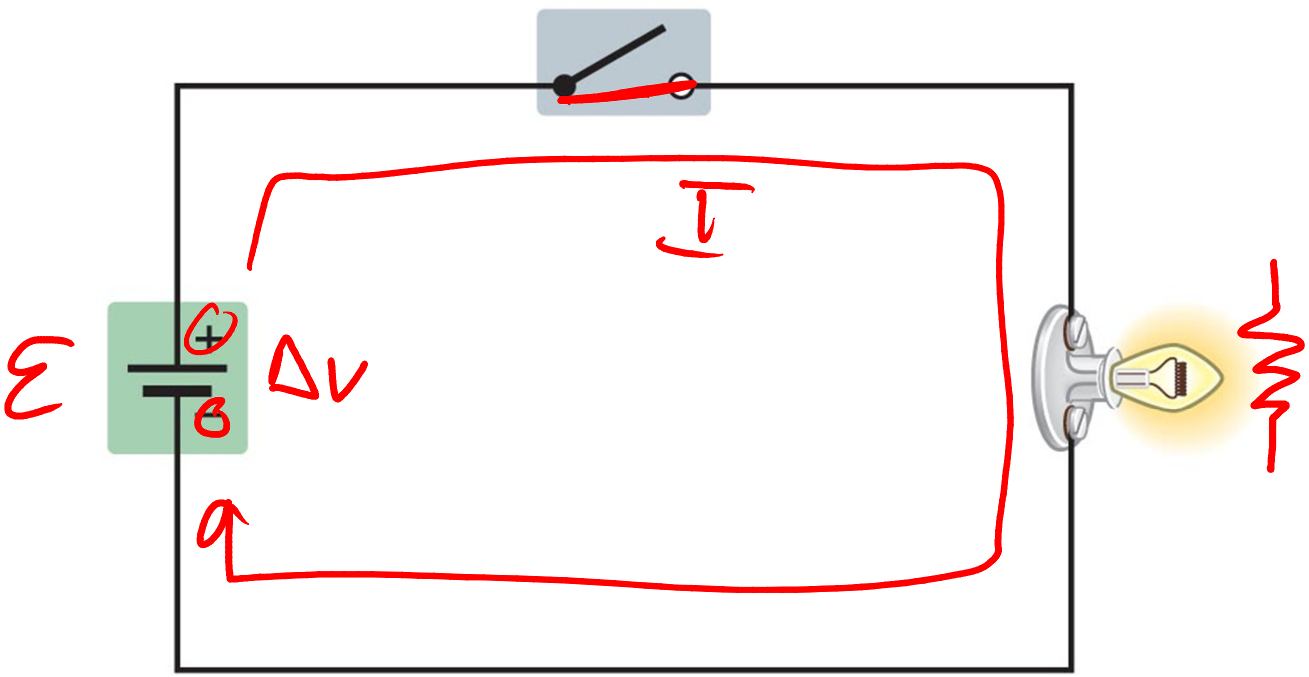
(a) Equal potential energy → no flow



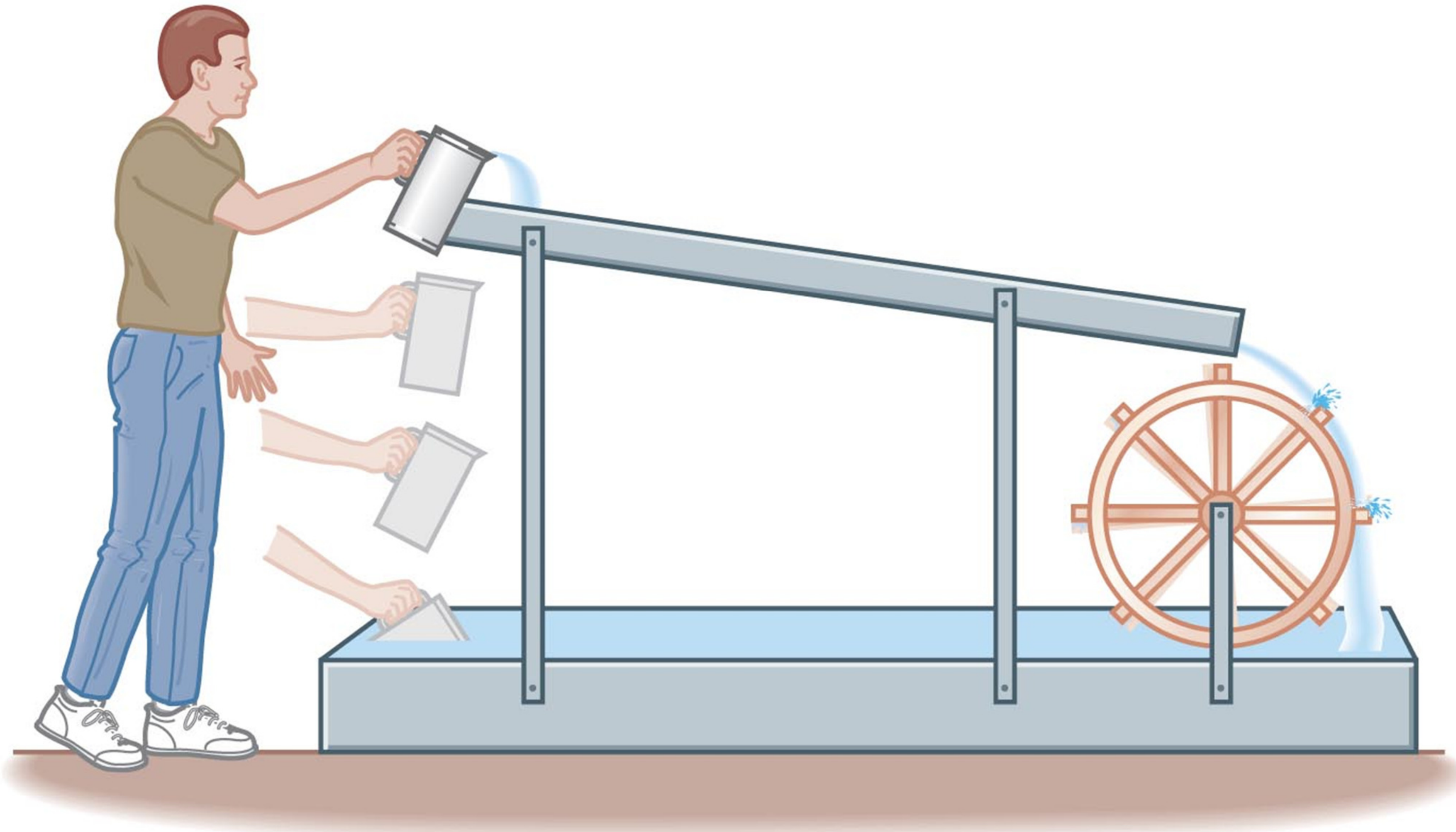
(b) Water flows from high potential energy to low

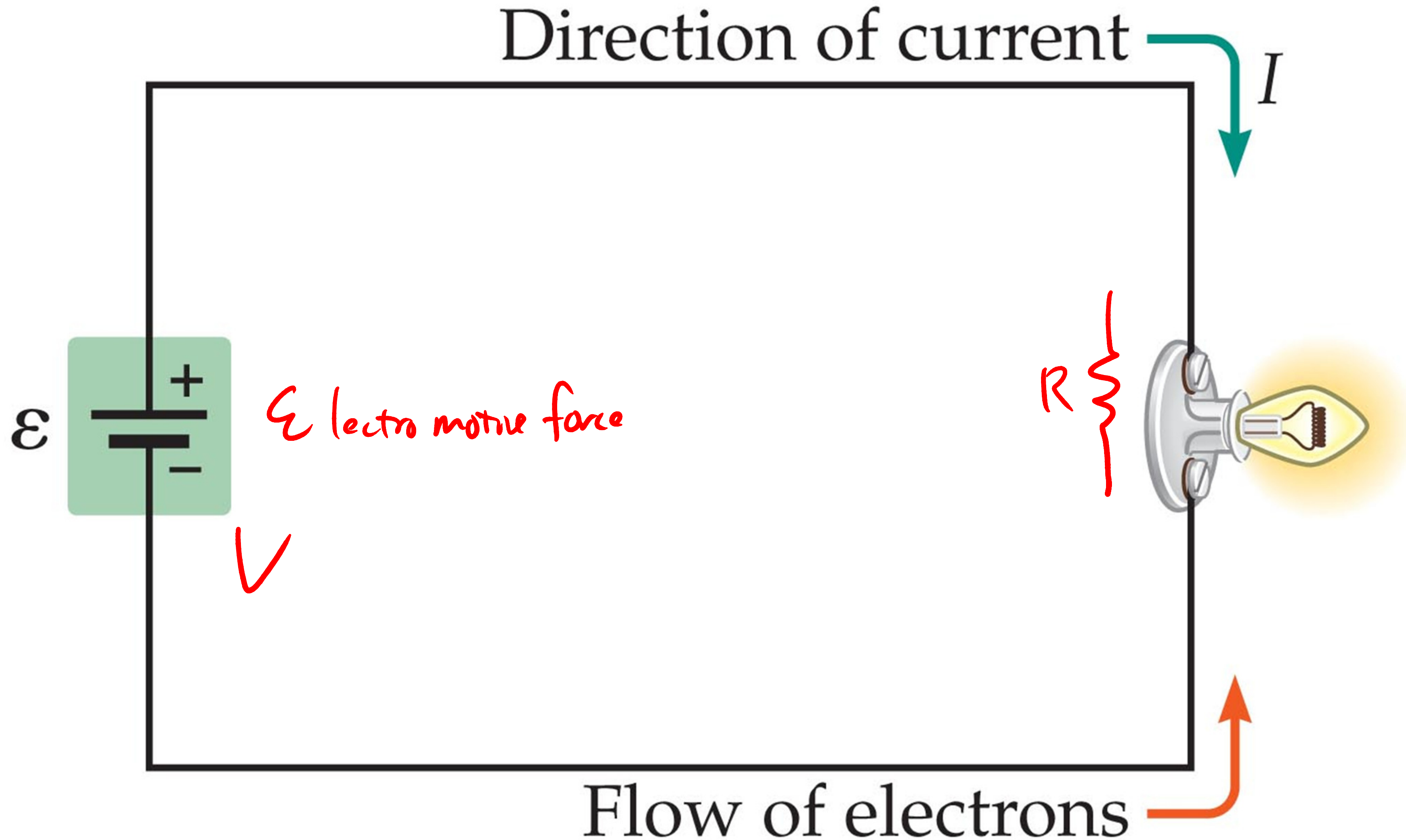


(a) A simple flashlight



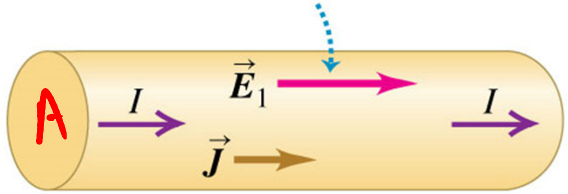
(b) Circuit diagram for flashlight



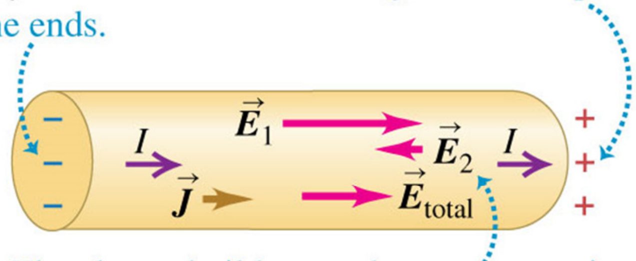

Direction of current
I
ε
+
−
Electromotive force
V
R
Flow of electrons

Why no E in a conductor left alone?

(a) An electric field $\vec{E}_1$ produced inside an isolated conductor causes a current.

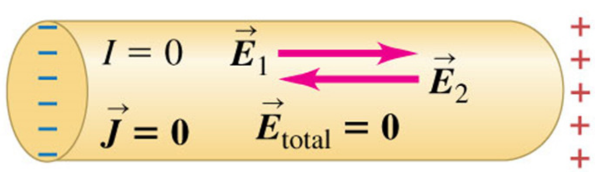


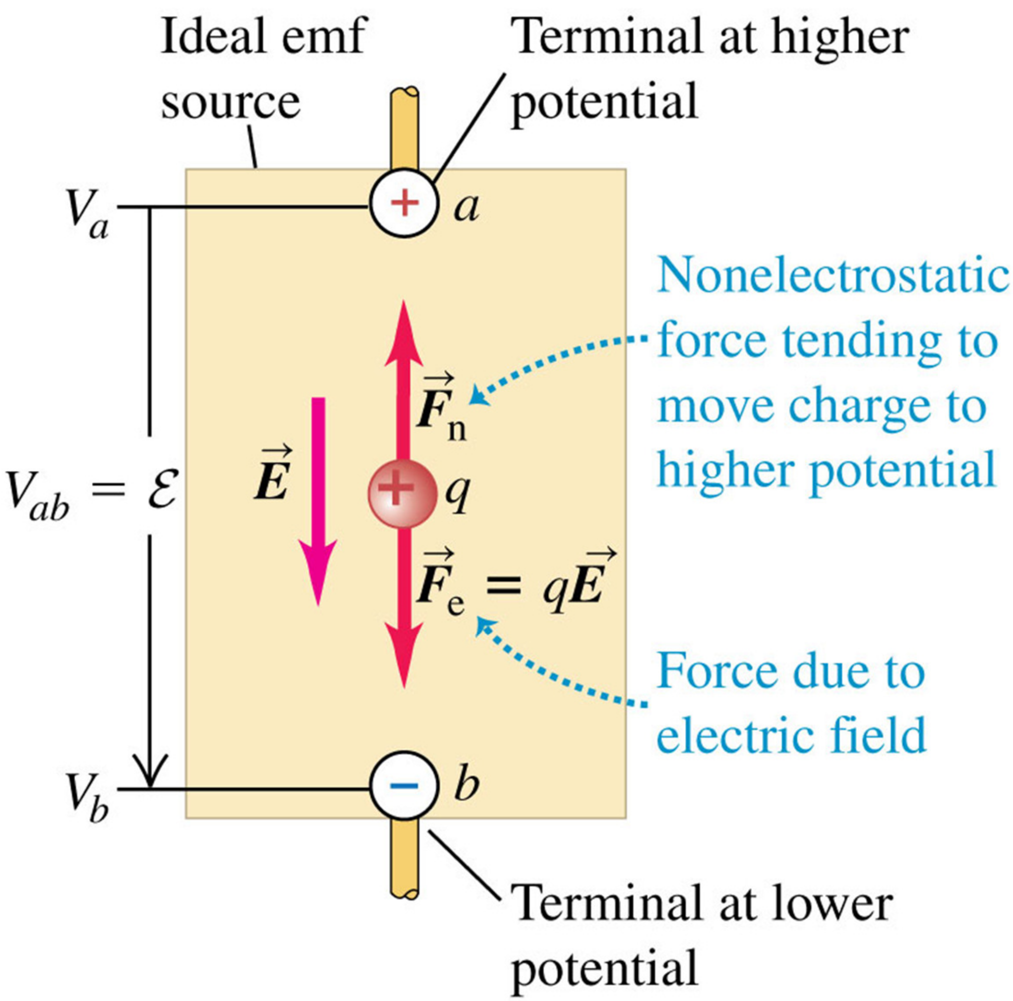
(b) The current causes charge to build up at the ends.



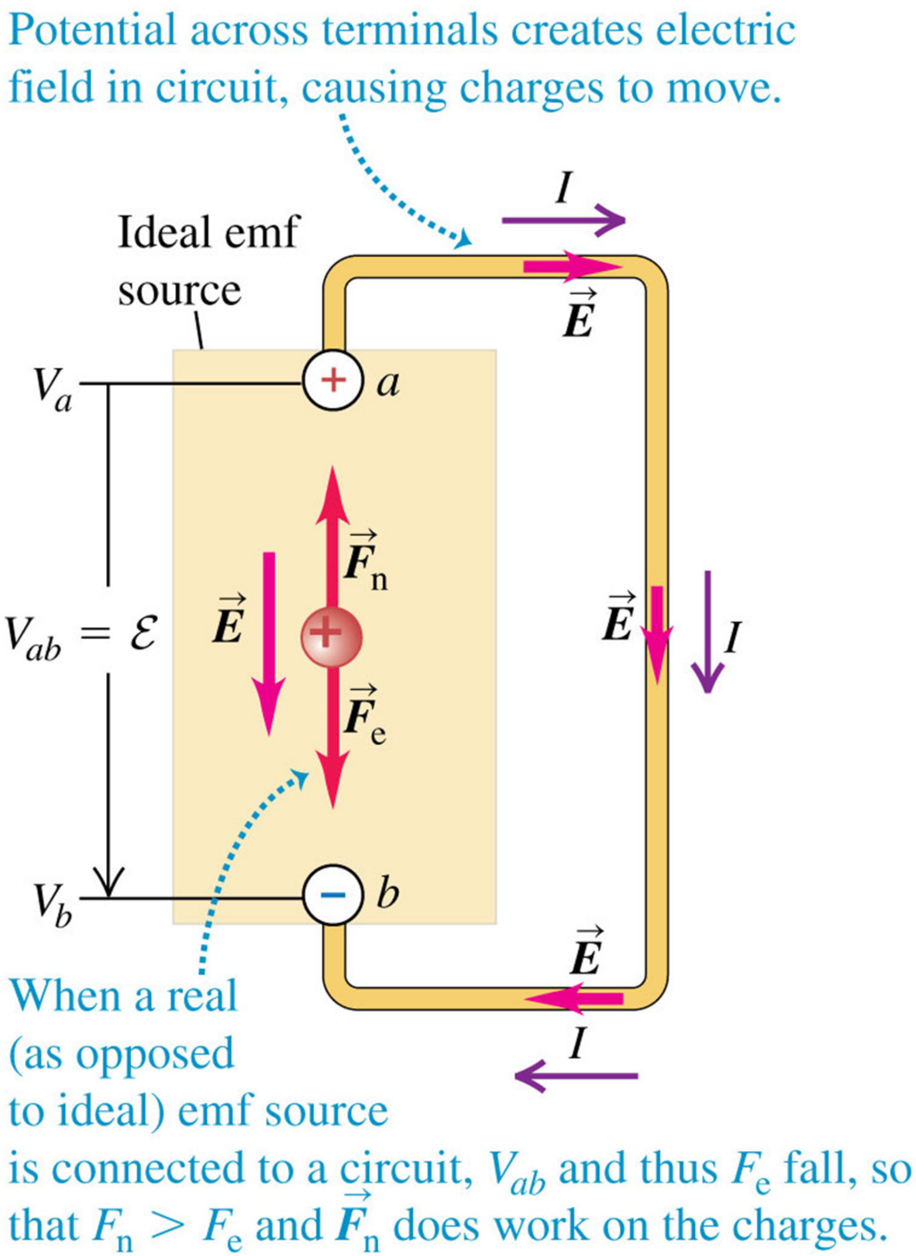
The charge buildup produces an opposing field $\vec{E}_2$, thus reducing the current.

(c) After a very short time $\vec{E}_2$ has the same magnitude as $\vec{E}_1$; then the total field is $\vec{E}_{total} = \mathbf{0}$ and the current stops completely.

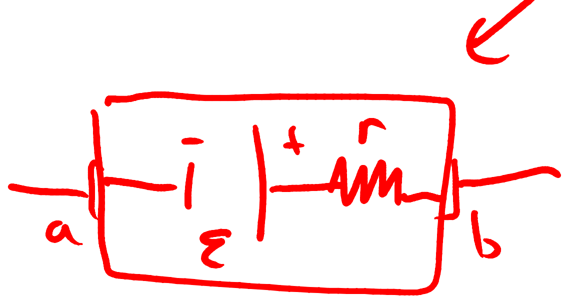




When the emf source is not part of a closed circuit, $F_n = F_e$ and there is no net motion of charge between the terminals.


Potential across terminals creates electric field in circuit, causing charges to move.
Ideal emf source
I
$\vec{E}$
V_a
a
$\vec{F}_n$
$\vec{E}$
$V_{ab} = \mathcal{E}$
$\vec{E}$
I
$\vec{F}_e$
V_b
b
$\vec{E}$
I
When a real (as opposed to ideal) emf source is connected to a circuit, V_{ab} and thus F_e fall, so that $F_n > F_e$ and $\vec{F}_n$ does work on the charges.

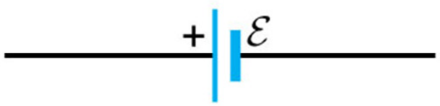
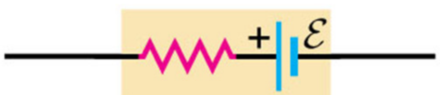
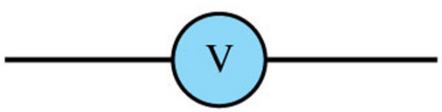
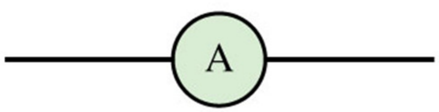
Non-ideal voltage source

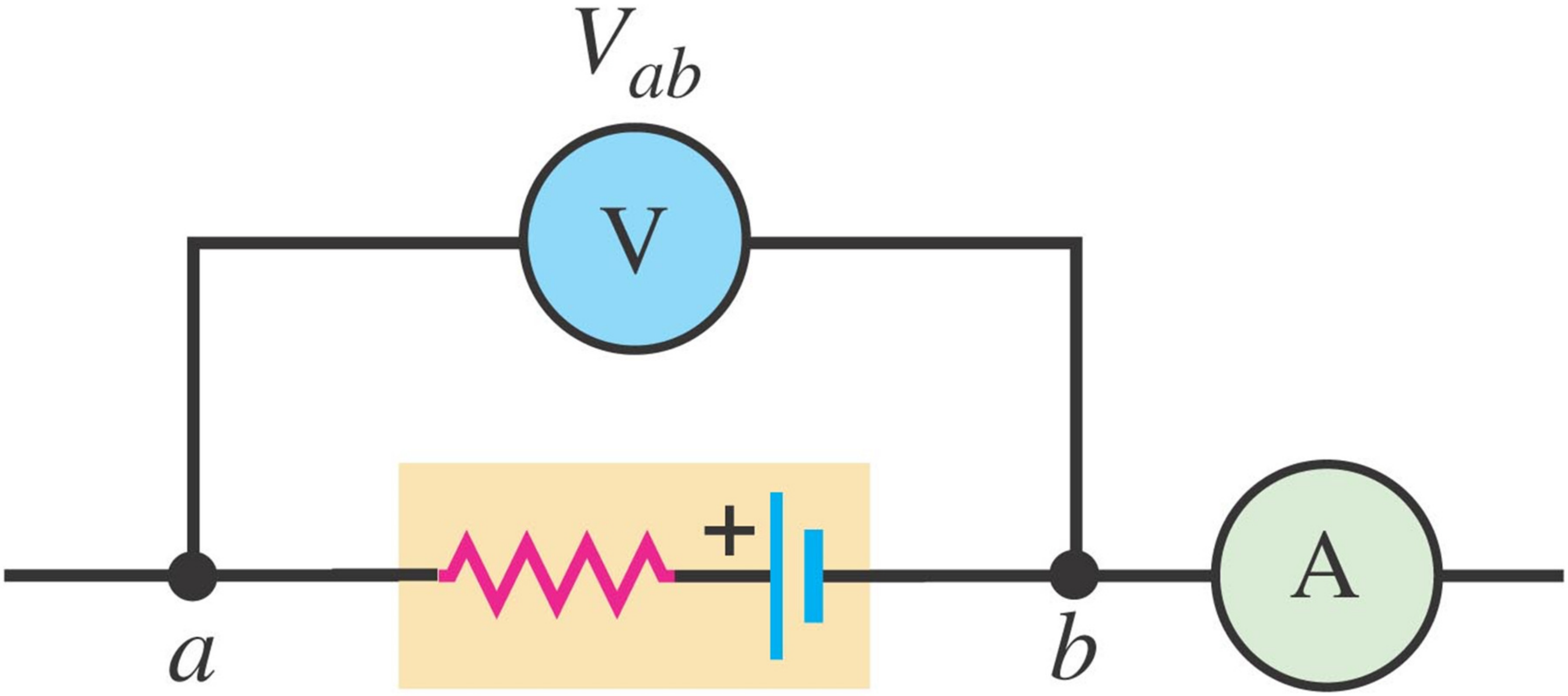


$$\Delta U_r = I r$$

$$U_{ab} = \varepsilon - I r$$

Table 25.4 Symbols for Circuit Diagrams

	Conductor with negligible resistance
	Resistor
	Source of emf (longer vertical line always represents the positive terminal, usually the terminal with higher potential)
 or 	Source of emf with internal resistance r (r can be placed on either side)
	Voltmeter (measures potential difference between its terminals)
	Ammeter (measures current through it)

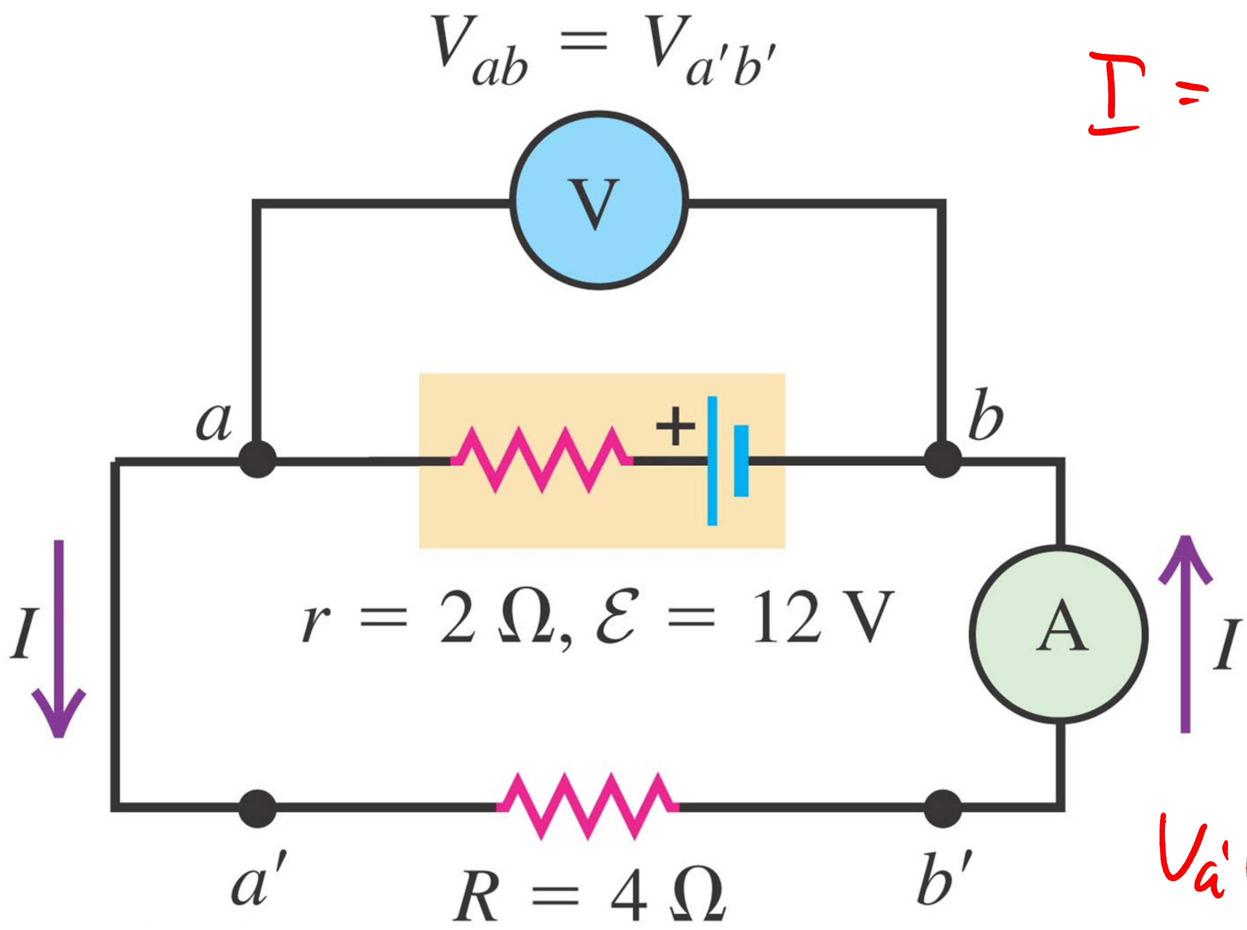


$r = 2\,\Omega,\ \mathcal{E} = 12\text{ V}$

no circuit, so Ⓐ reads 0 A

no current, $\Delta V_r = I r = 0 r = 0$

$\therefore V_{AB} = 12V$



$V = IR$

$I = V/R = \frac{12V}{(2+4)\Omega}$

$I = 2A$

$\mathcal{E} - Ir$

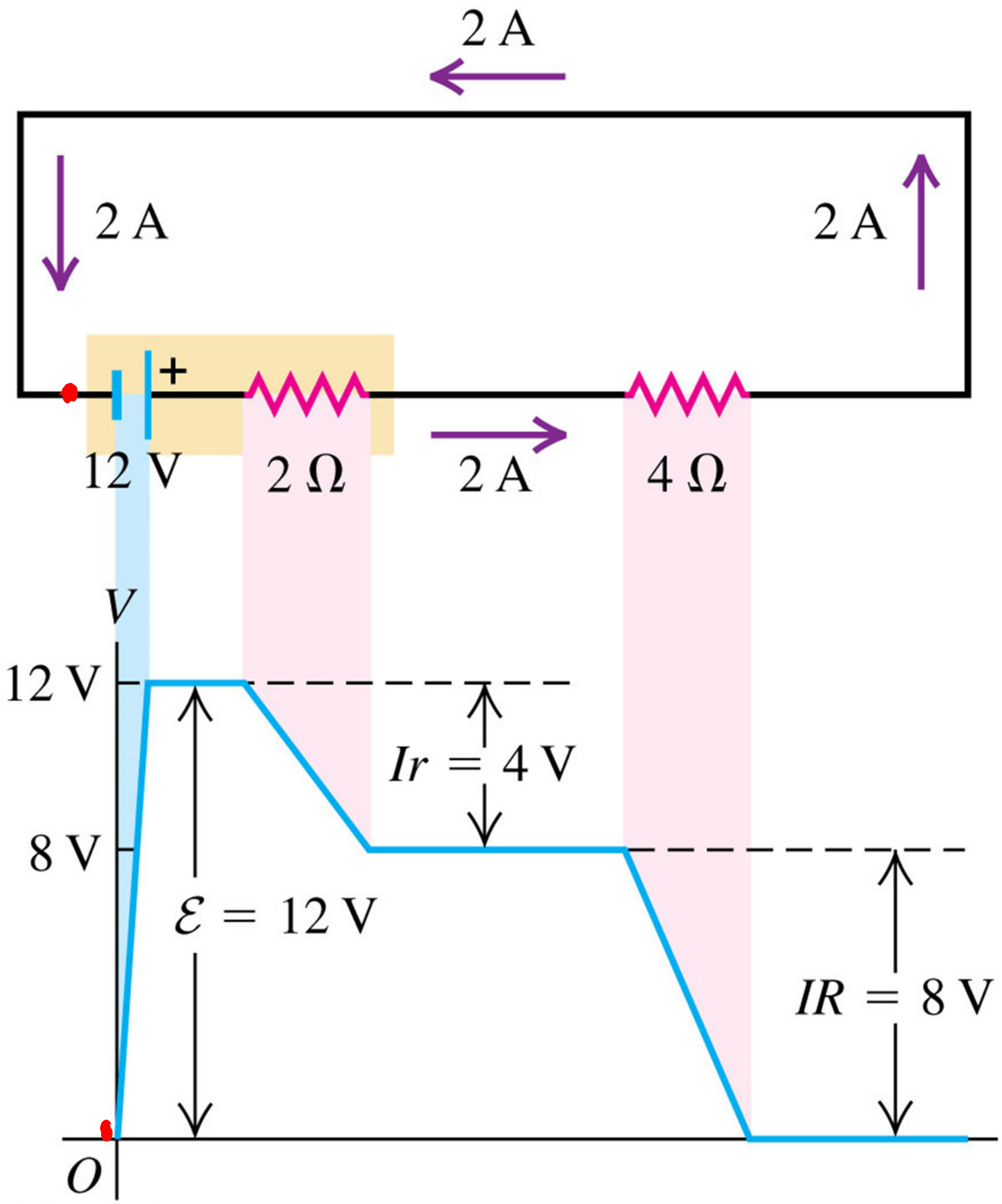
$V_{ab} = 12V - 2A \cdot 2\Omega$

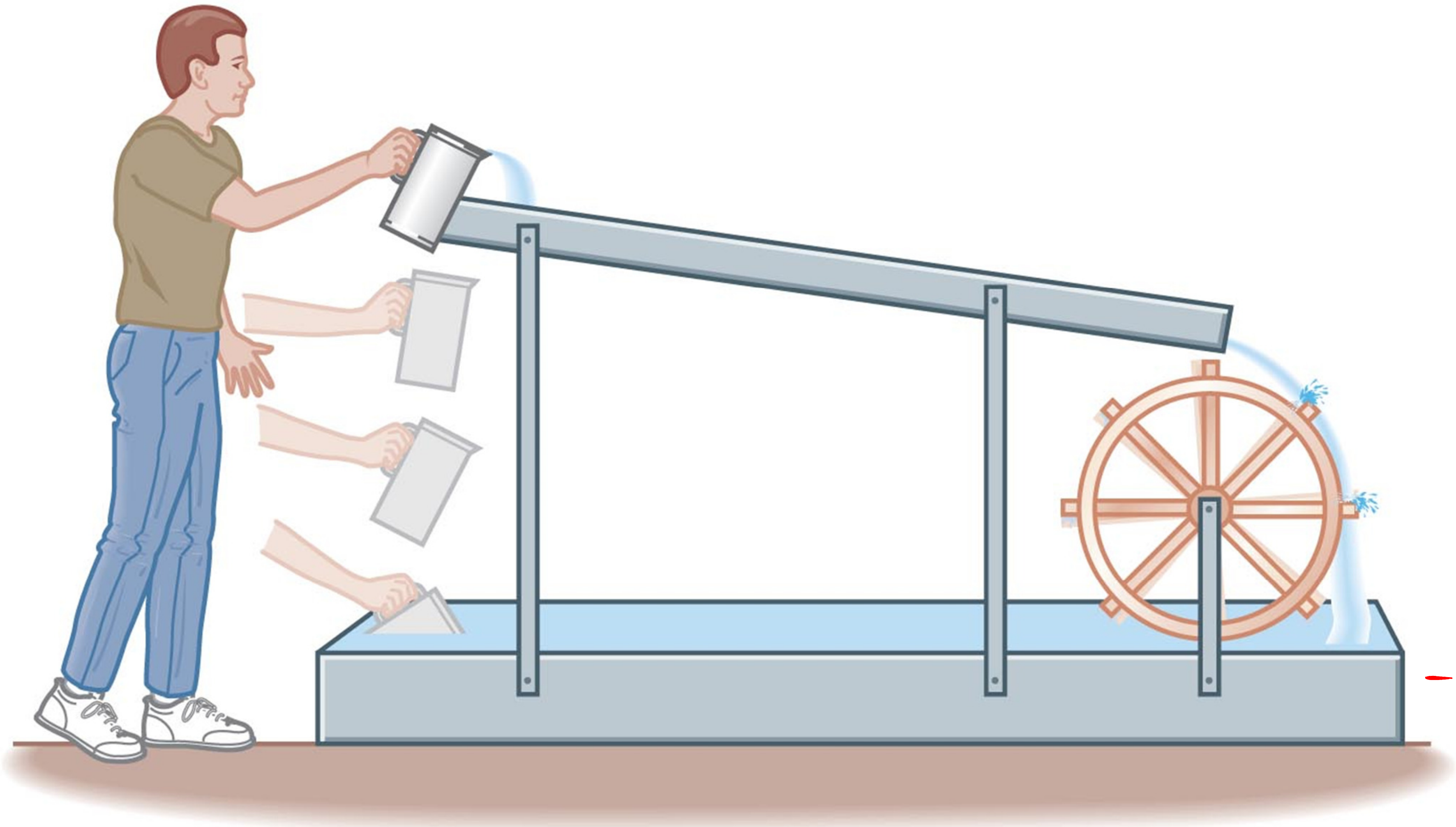
$= 8V$

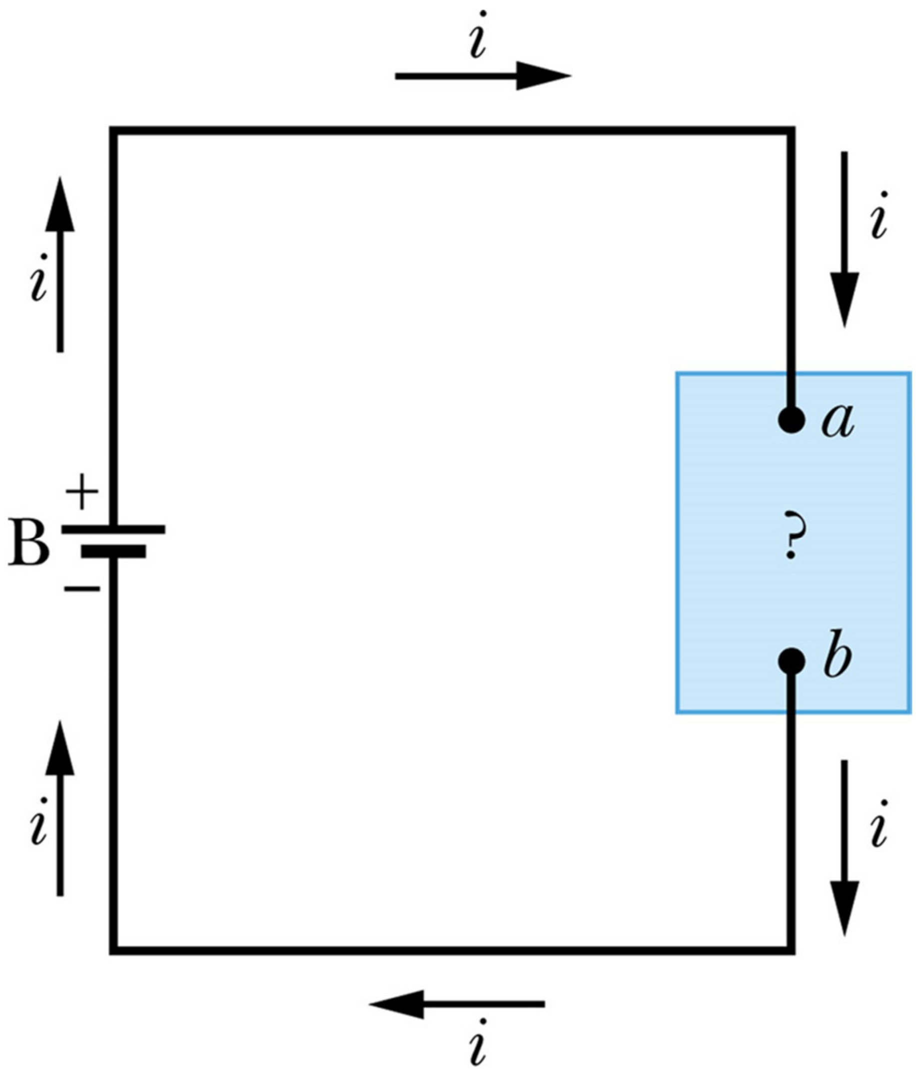
$V_{a'b'} = IR$

$= (2A)(4\Omega)$

$= 8V$


2 A
2 A
2 A
+
12 V
2 Ω
2 A
4 Ω
V
12 V
8 V
Ir = 4 V
ℰ = 12 V
IR = 8 V
O





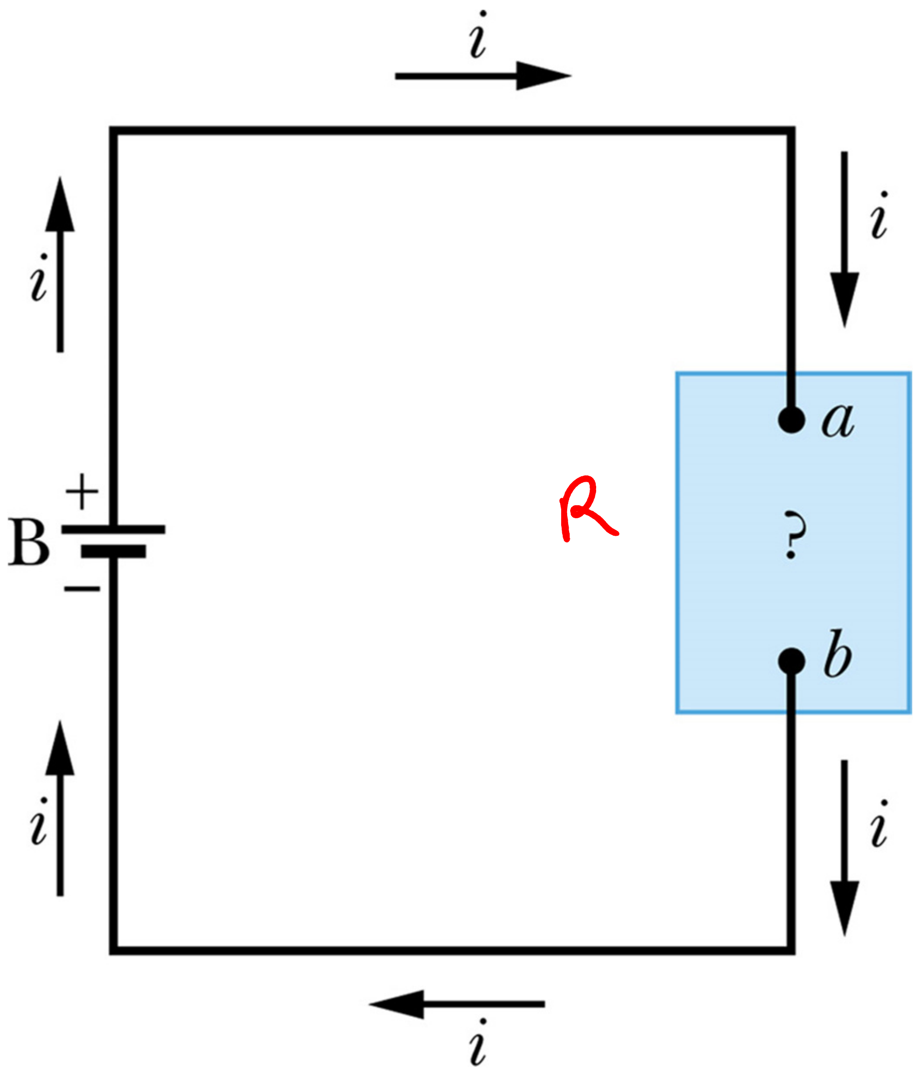
$$U = qV$$

$$\frac{dU}{dt} = \frac{dq}{dt}V + q\frac{dV}{dt}$$

$J/s \qquad C/s \; A$

$$P = IV + q\frac{dV}{dt} \to 0$$

$$P = VI$$



if "Ohmic" $V = IR$

$P = VI$

subst in to elim. V

$P = VI = (IR)\, I$

$P = I^2 R$

subst. to elim I $\left(I = \frac{V}{R}\right)$

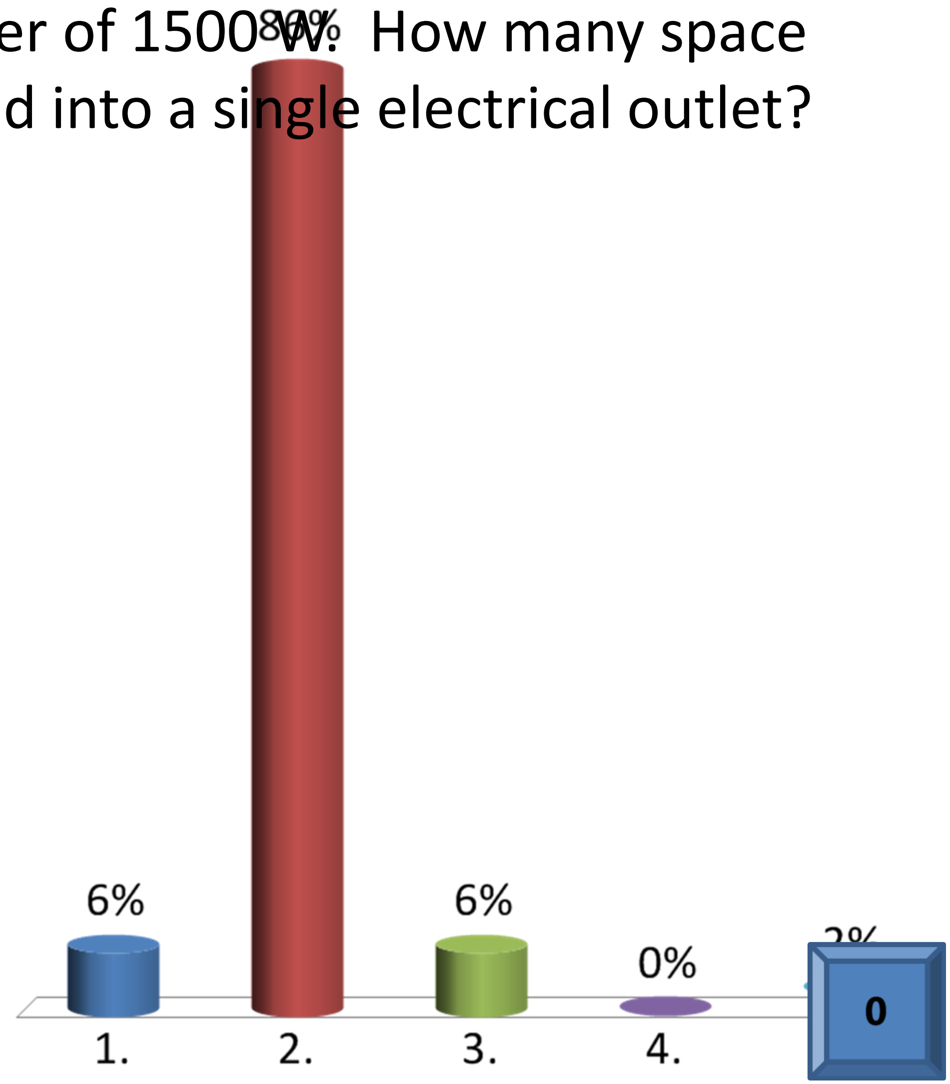
$P = \frac{V^2}{R}$

OHM NEVER FORGOT HIS DYING UNCLE'S ADVICE.

Ohm
+
Spiderman
=
xkcd.com

The insulated wiring in a house can safely carry a maximum current of 15 A. The electrical outlets in the house provide an voltage of 120 V. A space heater when plugged into the outlet operates at an average power of 1500 W. How many space heaters can safely be plugged into a single electrical outlet?

1. Zero
2. One ✓
3. Two
4. Three
5. Four



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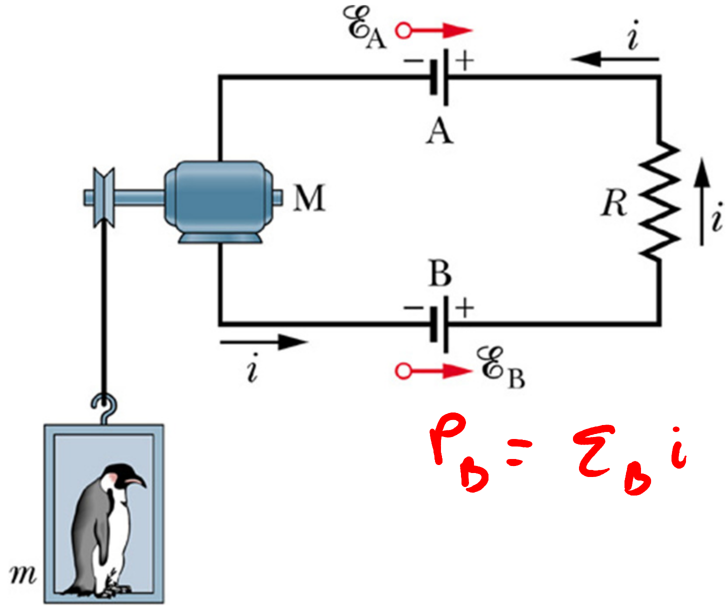


(a)

$$\text{If } \mathcal{E}_B > \mathcal{E}_A$$

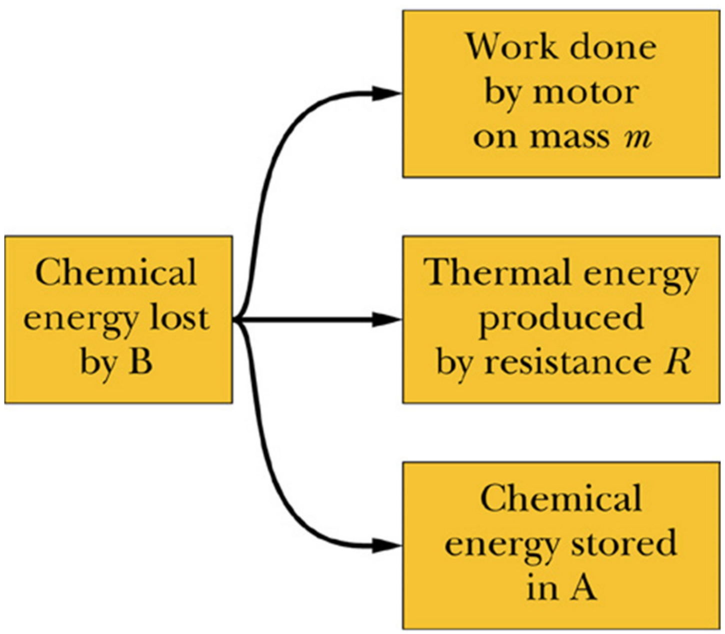
$$P_R = i^2 R$$

$$P_B = \mathcal{E}_B\, i$$

$$P_A = \mathcal{E}_A\, i$$

$$P_m = \Delta V_m \cdot i$$

$$P_p = \frac{mgh}{\Delta t}$$

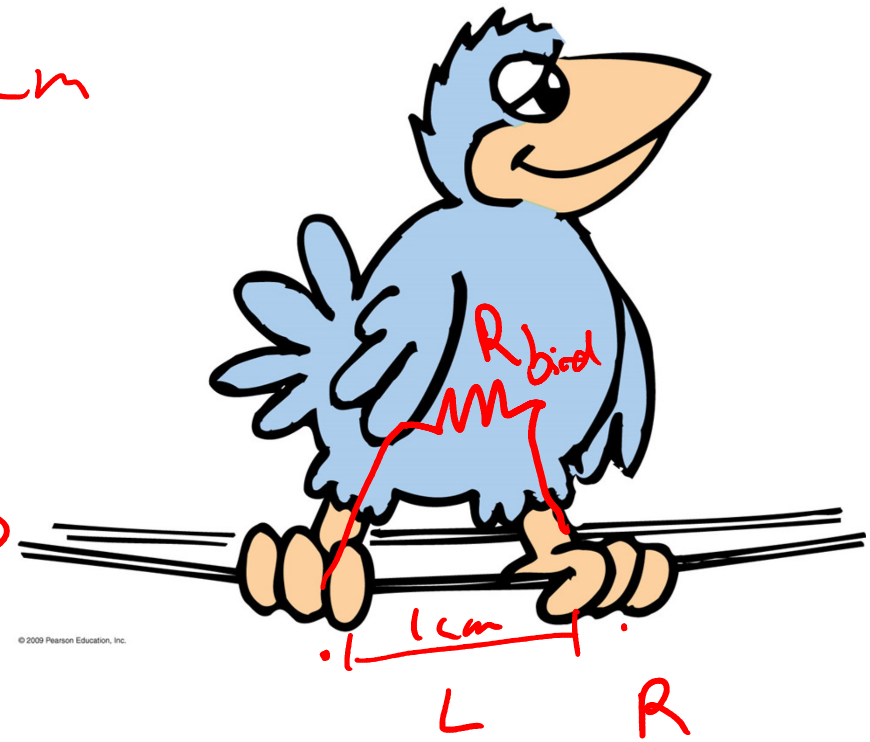


(b)

$\rho_{copper} = 1.69 \times 10^{-8}\ \Omega m$

1cm diameter

1 kA →



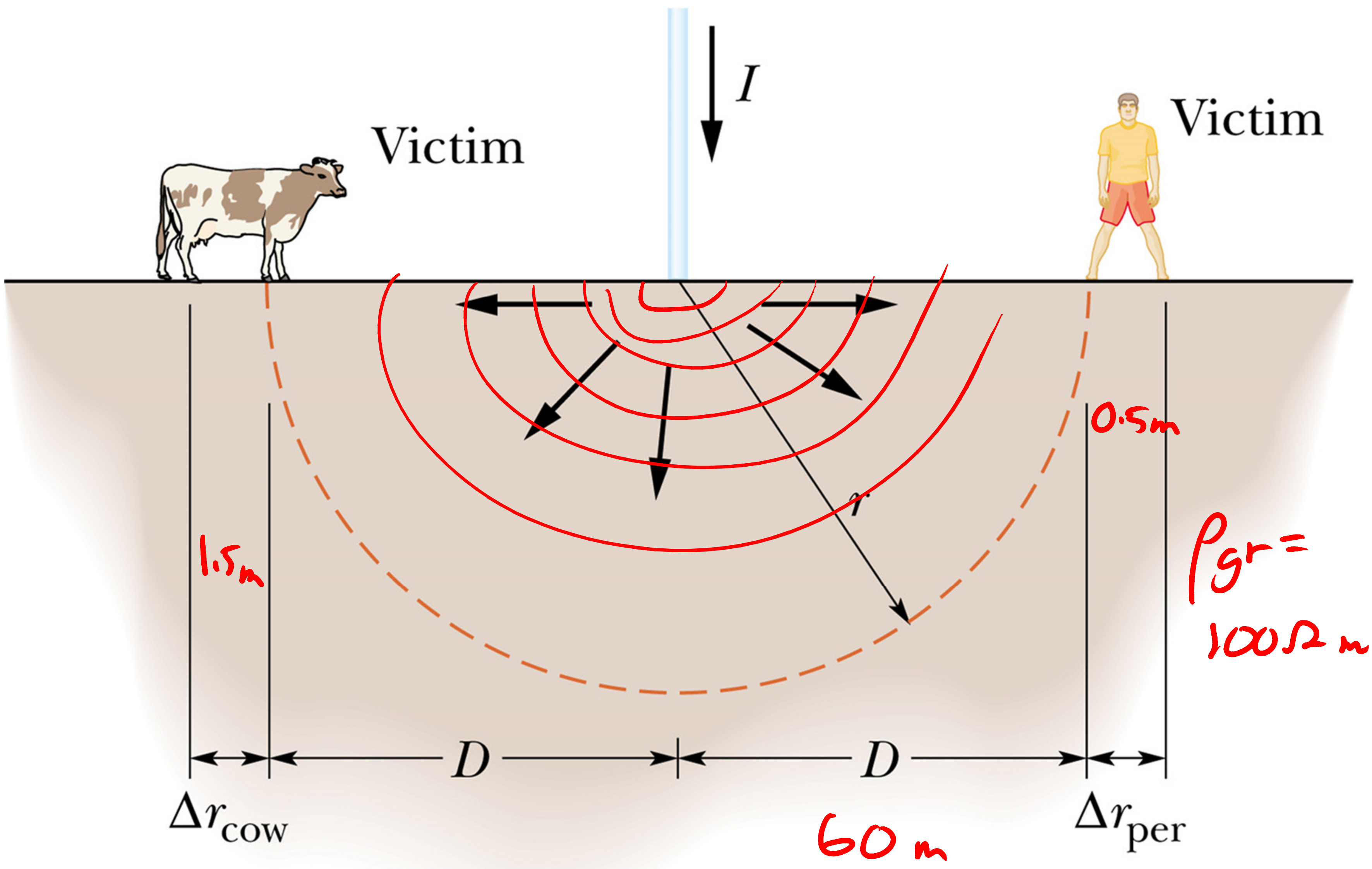
$$\frac{R}{L} = \frac{\rho}{A} = \frac{1.69 \times 10^{-8}\ \Omega m}{\pi (0.005\ m)^2} = 2.15 \times 10^{-4}\ \Omega/m$$

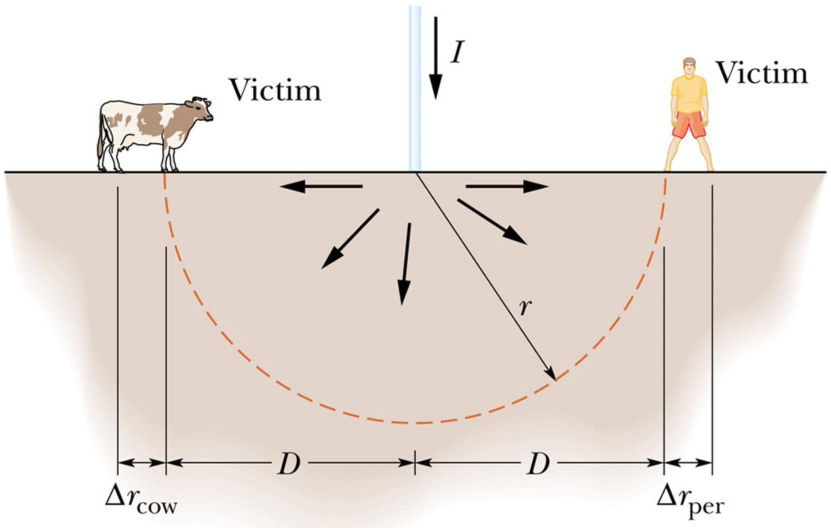
$$R_{wire} = \frac{R}{L} \cdot L = 2.15 \times 10^{-6}\ \Omega$$

$$\Delta V = IR = 2.15\ mV$$

100 kA

R mammal = 4.0 kΩ





$$J = I/A = \frac{I}{2\pi r^2}$$

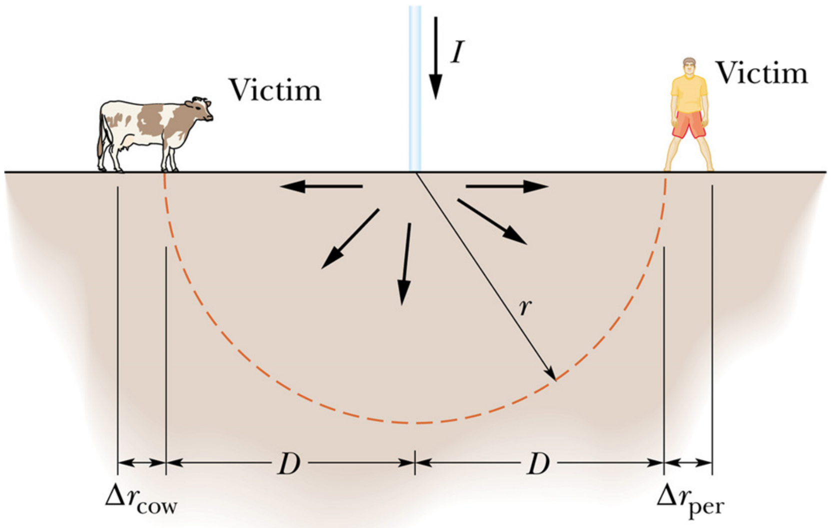
$$E = \rho J = \frac{\rho_{gr} I}{2\pi r^2}$$

$|E||dr|\cos 0$

$$\Delta V = -\int \vec{E}\cdot d\vec{s} \qquad (ds = dr)$$

$$= -\int \frac{\rho_{gr} I}{2\pi r^2}\, dr$$

$$\Delta V = -\frac{\rho_{gr} I}{2\pi}\int_{r}^{r+\Delta r} \frac{dr}{r^2}$$



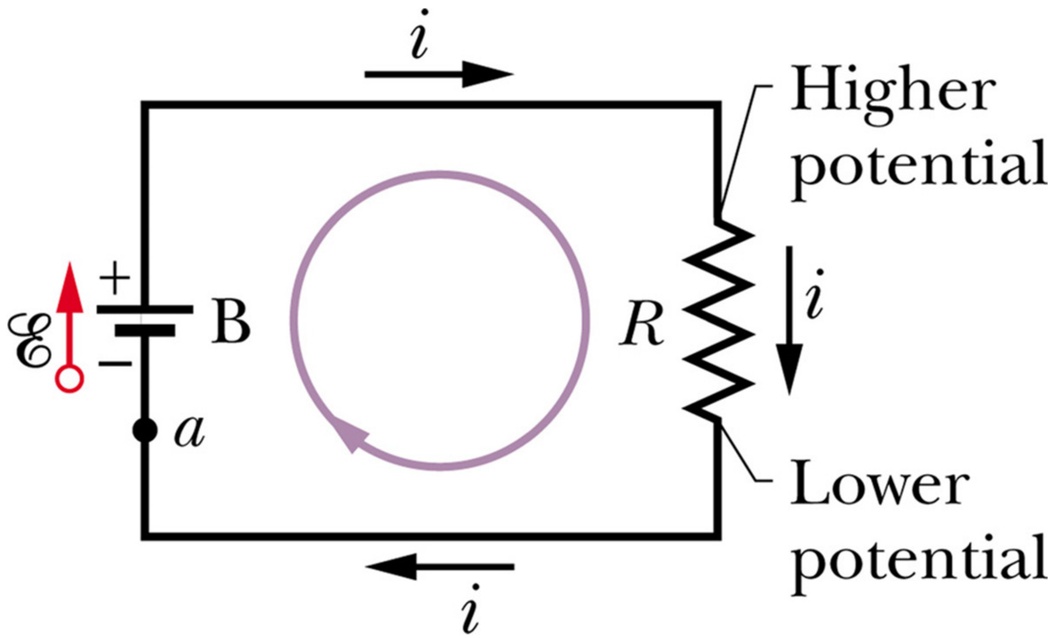
$$\Delta V = -\frac{\rho_{gr} I}{2\pi} \Big|_{D}^{D+\Delta r} \left(\frac{-1}{r}\right)$$

$$= \frac{\rho_{gr} I}{2\pi}\left(\frac{1}{D+\Delta r} - \frac{1}{D}\right)$$

$$= \frac{\rho_{gr} I}{2\pi}\left(\frac{\Delta r}{D(D+\Delta r)}\right)$$

$$I_{person} = \frac{\Delta V_{person}}{R_{mammal}} = 54.8\ mA$$

Cow? $I_{cow} = 162\ mA$



Let's follow a little bit of charge dq as it goes around this circuit

$dq = I\,dt$

$dW = \mathcal{E}\,dq$ $\quad (V I)$

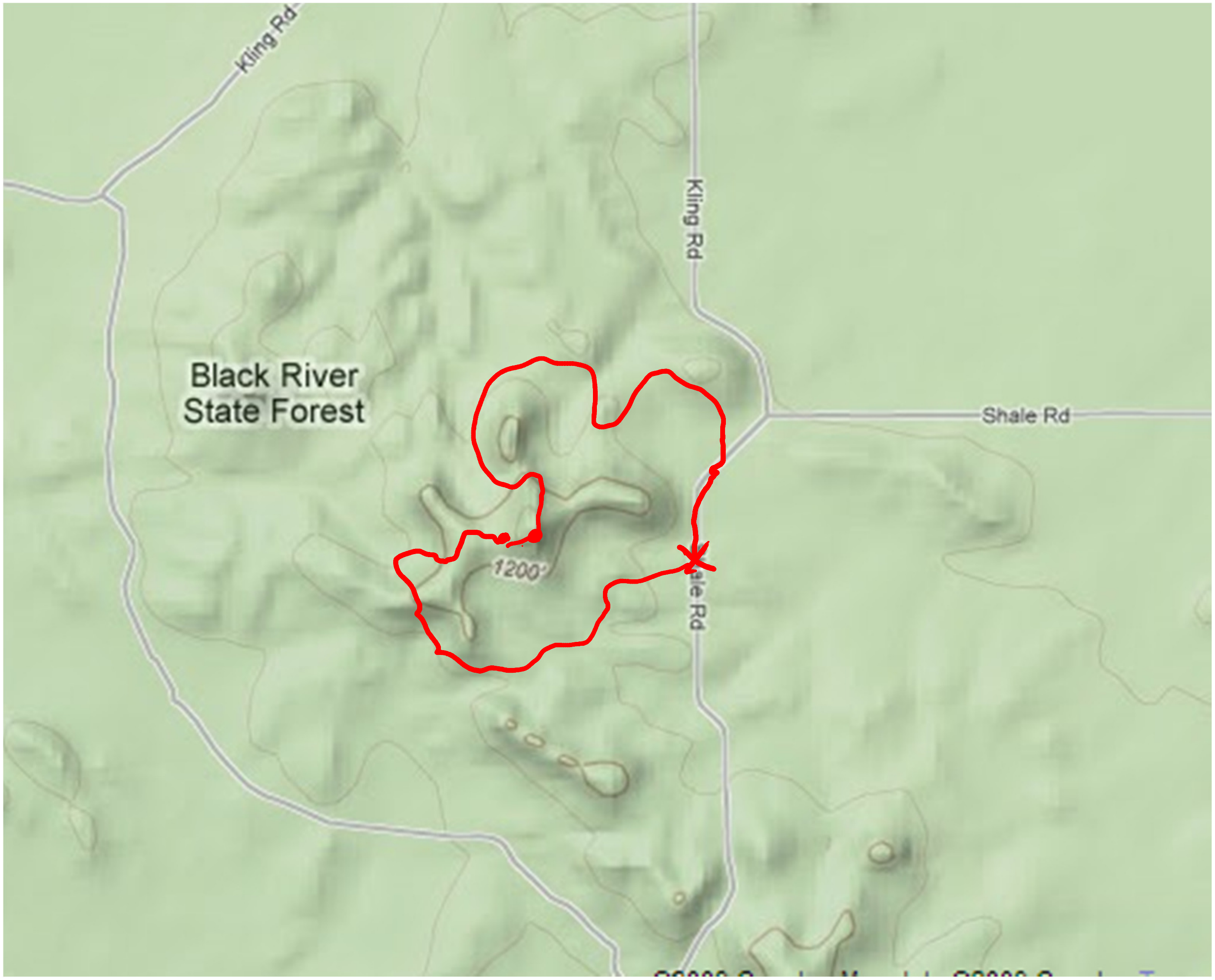
$= \mathcal{E} I\,dt$

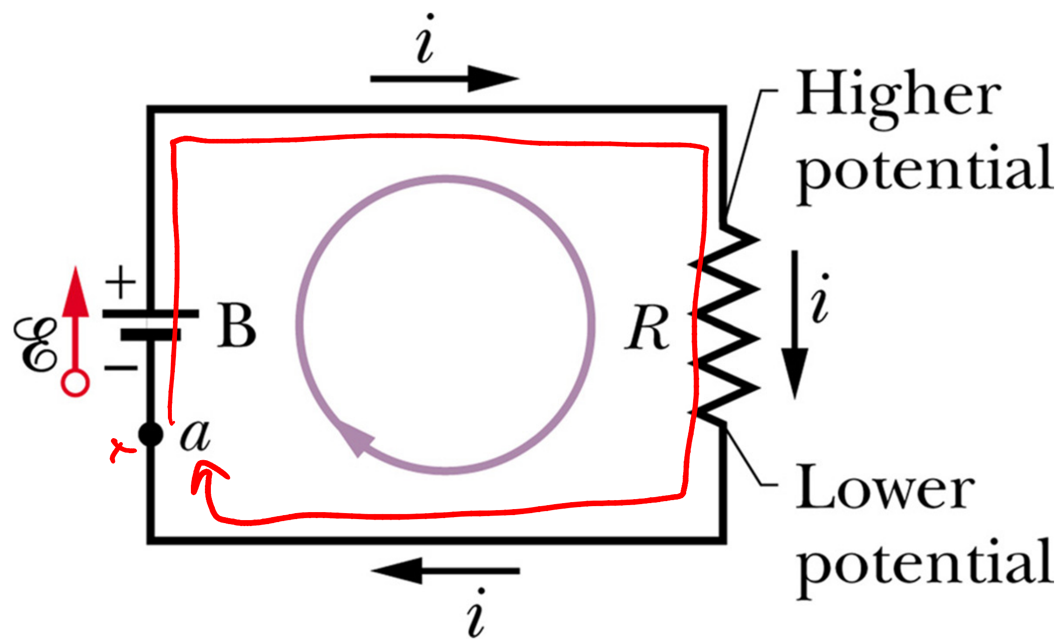
in R, $dW = I^2 R\,dt$

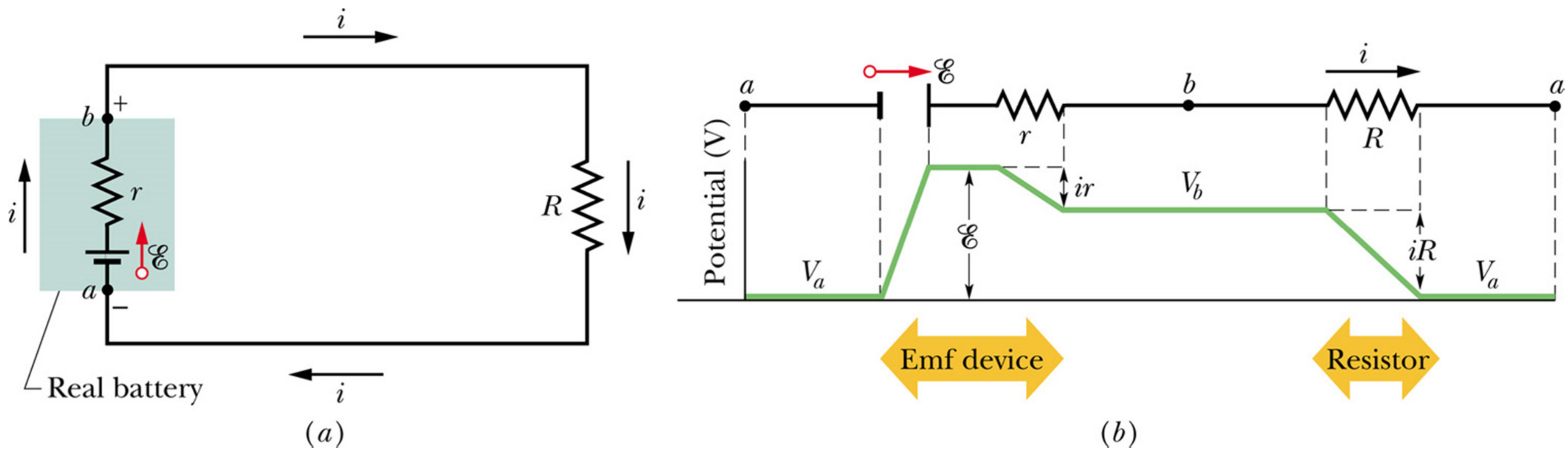
Cons. energy,

$\mathcal{E} I\,dt = I^2 R\,dt$

$\mathcal{E} = I R$


Kling Rd
Kling Rd
Black River
State Forest
Shale Rd
1200'


i
Higher
potential
+
B
R
i
−
a
Lower
potential
i

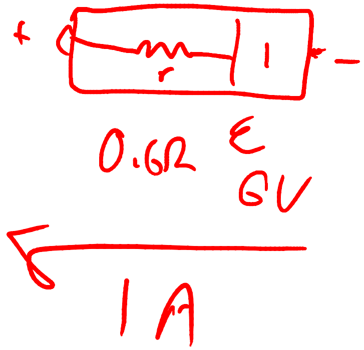


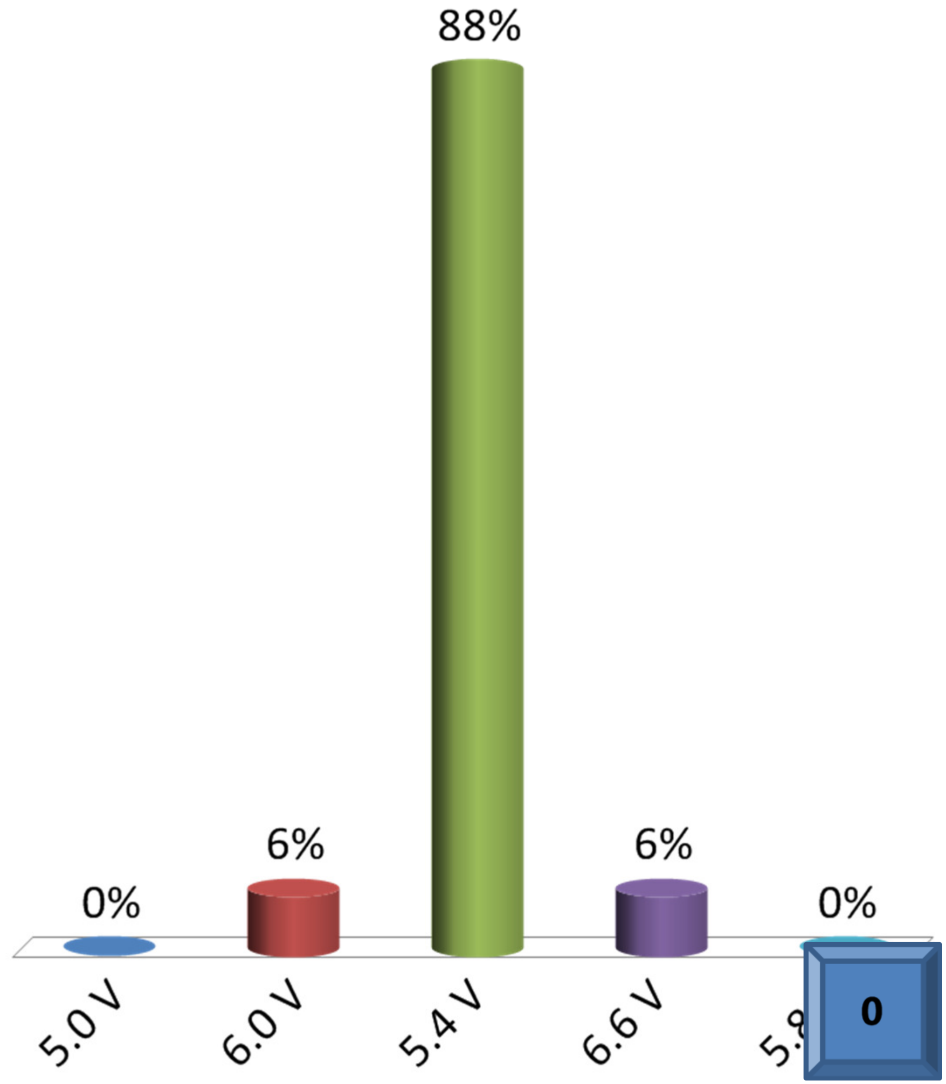
$$\varepsilon - Ir - IR = 0$$

$$I = \frac{\varepsilon}{R+r}$$

A non-ideal battery has a 6.0-V emf and an internal resistance of 0.6 Ω. Determine the terminal voltage when the current drawn from the battery is 1.0 A.

1. 5.0 V
2. 6.0 V
3. 5.4 V ✓
4. 6.6 V
5. 5.8 V





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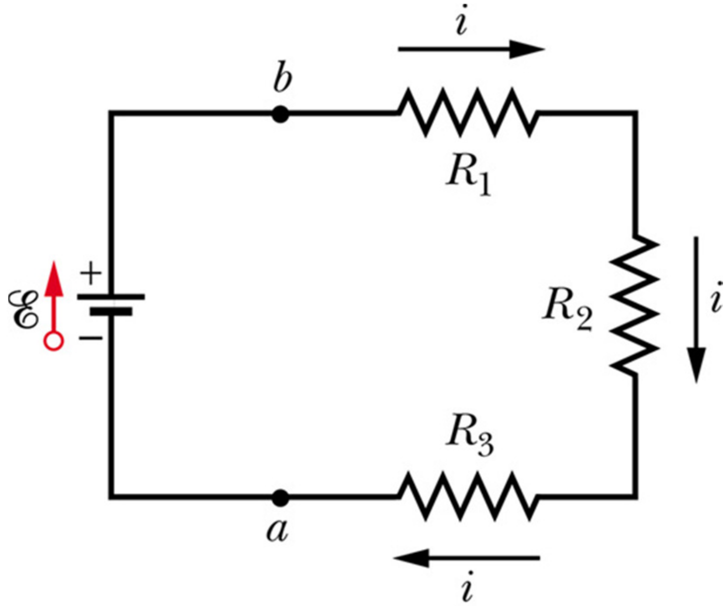
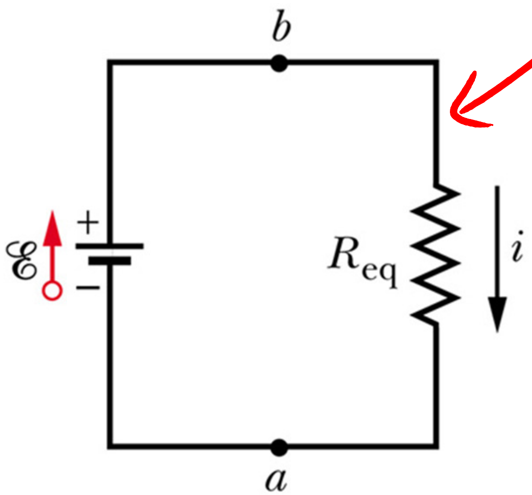


(a)



(b)

Kirchoff's Loop Rule

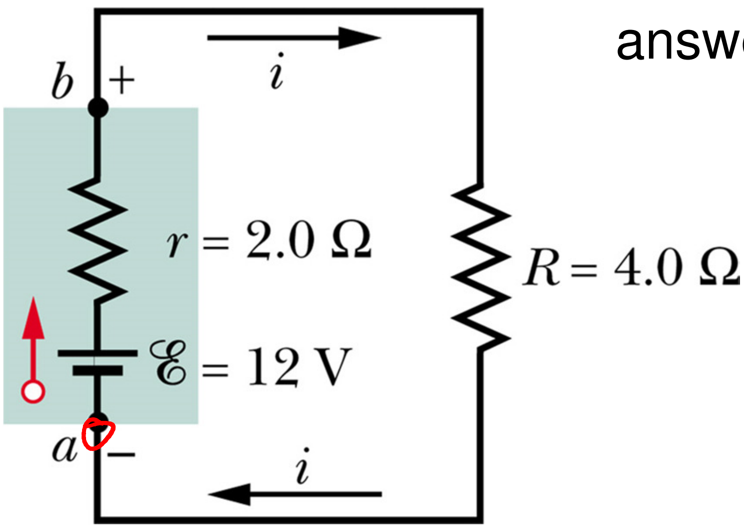
$$\Sigma \Delta V\text{s} = 0$$

$$+\mathcal{E} - IR_1 - IR_2 - IR_3 = 0$$

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

↳ R_{eq}

$$\mathcal{E} = I R_{eq}$$



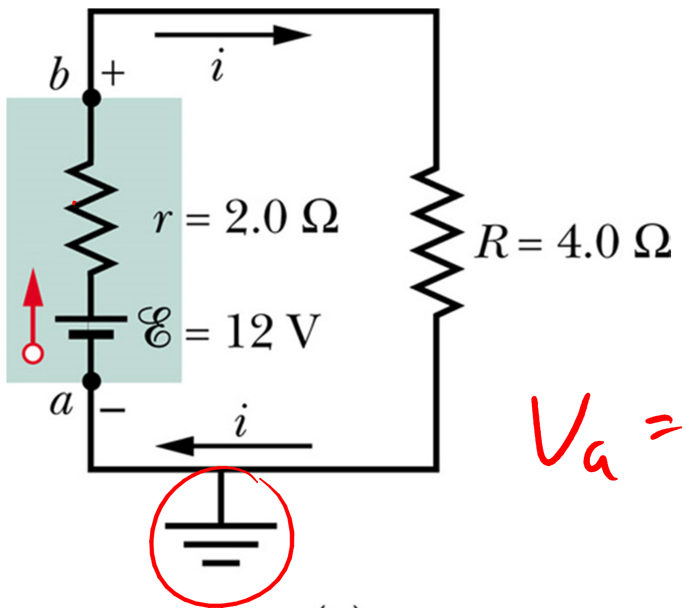
Let's use the loop rule to answer the last question

$$V_a + \mathcal{E} - Ir - IR = V_a$$

$$\mathcal{E} - Ir - IR = 0$$

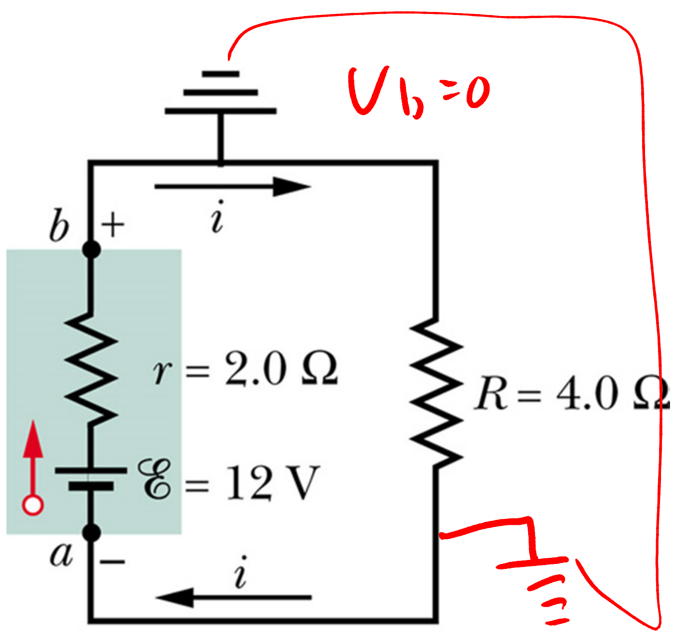
$$I = \frac{\mathcal{E}}{R + r}$$

(ground symbol) = Ground = $V = 0$



$V_a = 0$

(a)



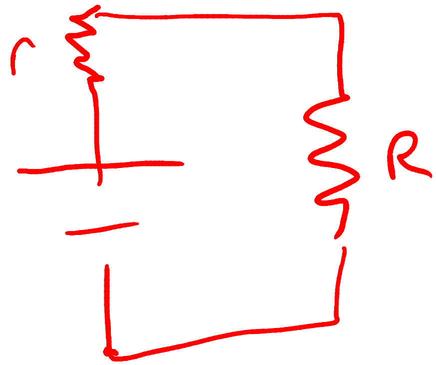
$V_b = 0$

(an unintentional short)

(b)

What's the power put out by this 9V battery
if the steel wool has R=0.4Ω and the battery's internal r=0.1Ω?

What's the power put out by this 9V battery
if the steel wool has R=0.4Ω and the battery's internal r=0.1Ω?



$$I = \frac{V}{r+R}$$

$$I = \frac{9V}{0.1\Omega + 0.4\Omega}$$

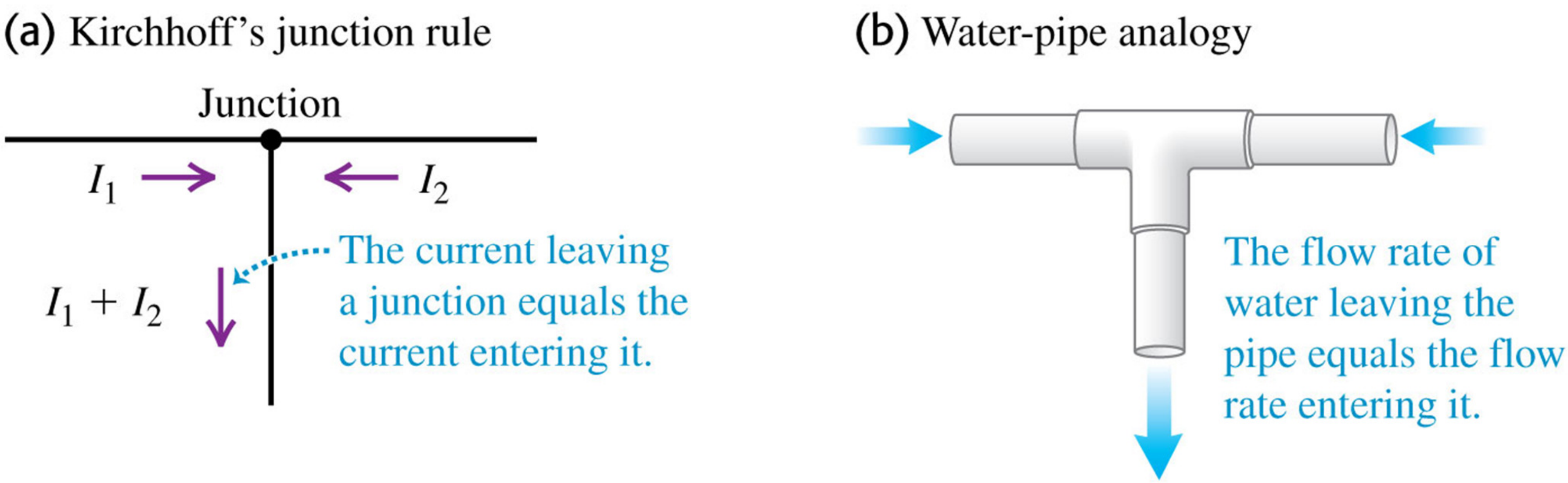
$$I = 18\,A$$

$$P = VI = 9V \cdot 18A = 162\,W$$

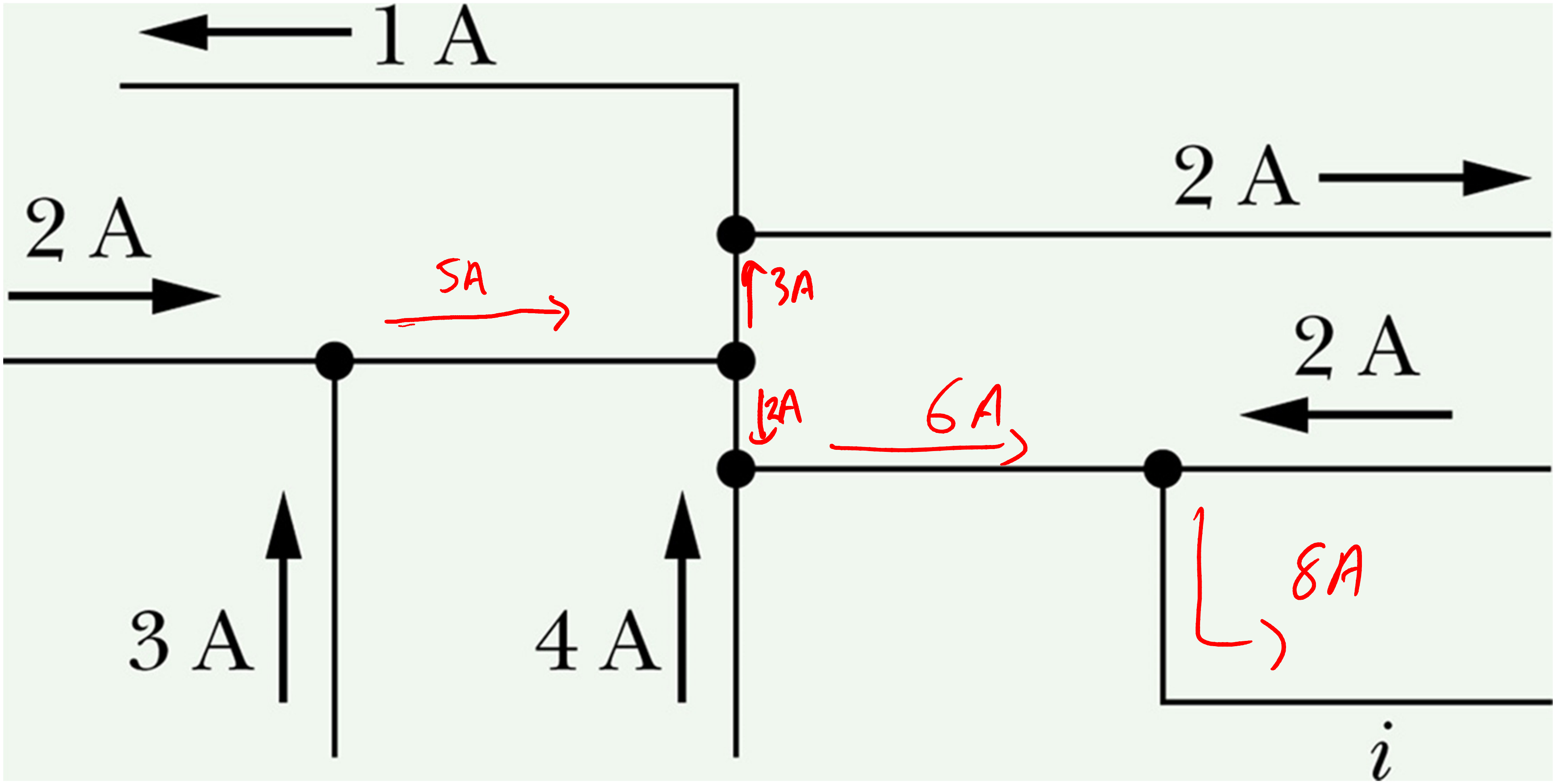
$$V = IR$$

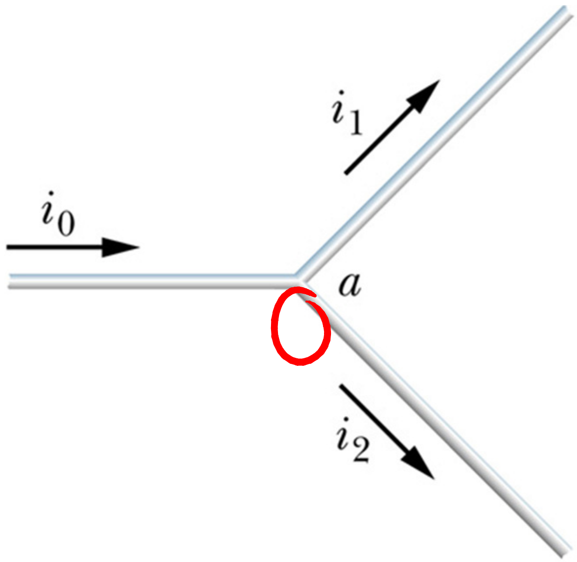
$$P_R = I^2 R = 129.6\,W$$

Cons of charge

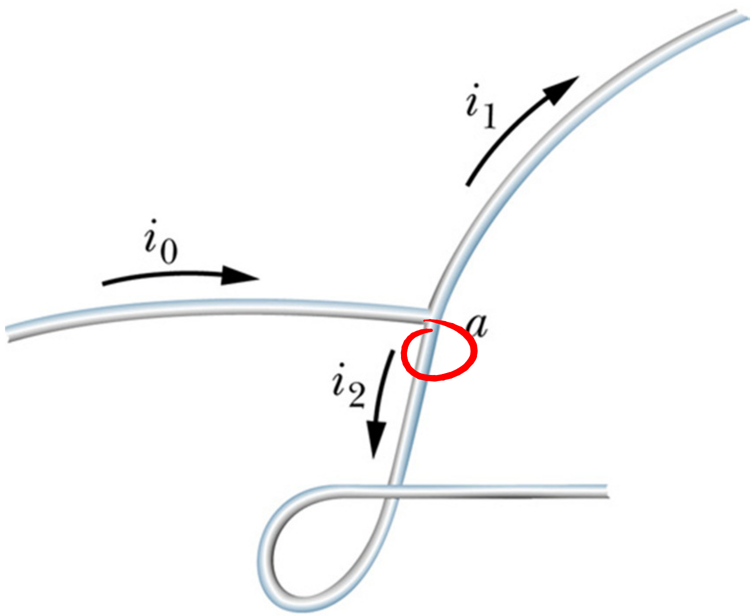


$$\sum I_{in} = \sum I_{out}$$


1 A
2 A
2 A
2 A
5A
3A
2A
6 A
8A
3 A
4 A
i



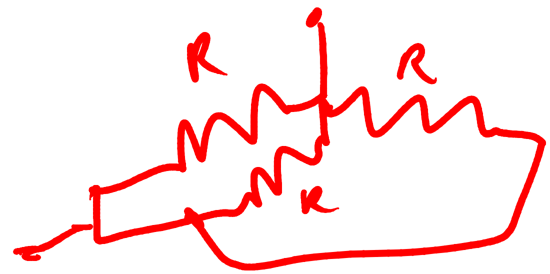
(a)

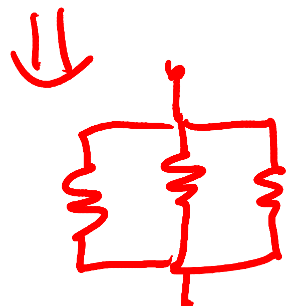


(b)

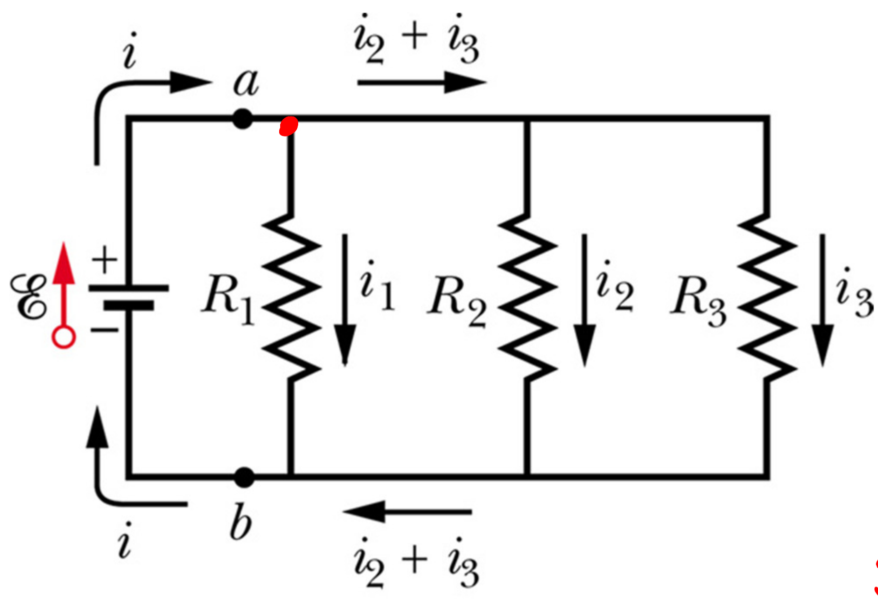
Conservation of charge

$$i_0 = i_1 + i_2$$

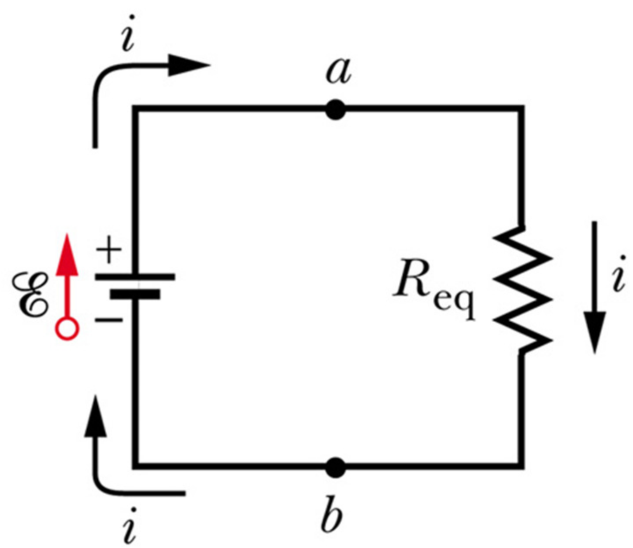




$$i_0 = i_1 + i_2$$



(a)



(b)

all R's have same V

∴ they're in parallel

$$I_1 = \frac{V_1}{R_1} \quad I_2 = \frac{V_2}{R_2} \quad I_3 = \frac{V_3}{R_3}$$

but $V = V_1 = V_2 = V_3$

Junction rule: $I = I_1 + I_2 + I_3$

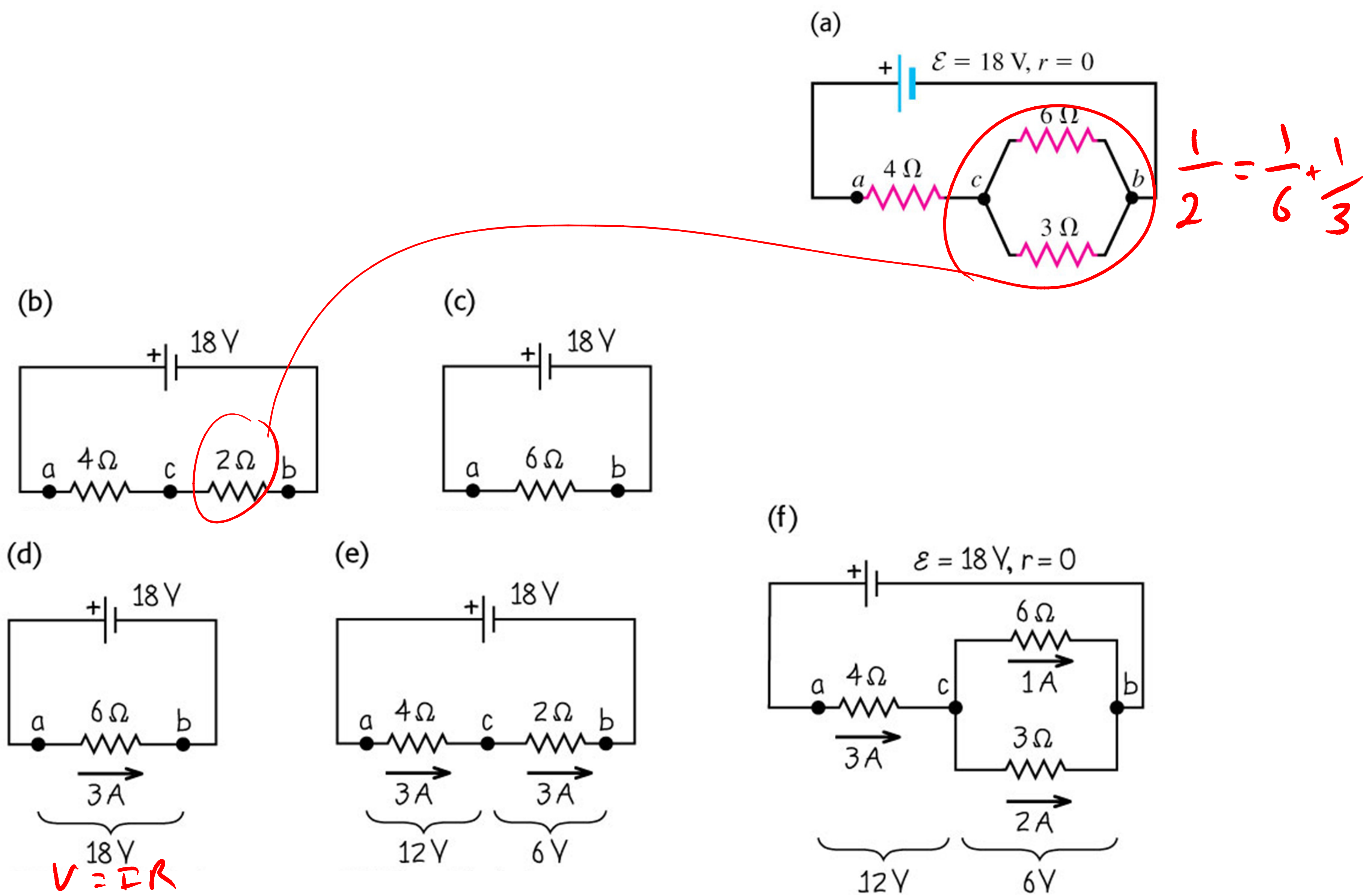
$$I = V/R_1 + V/R_2 + V/R_3$$

$$I = V\left(1/R_1 + 1/R_2 + 1/R_3\right)$$

$$V = I\left(\frac{1}{1/R_1 + 1/R_2 + 1/R_3}\right)$$

→ R_{eq}

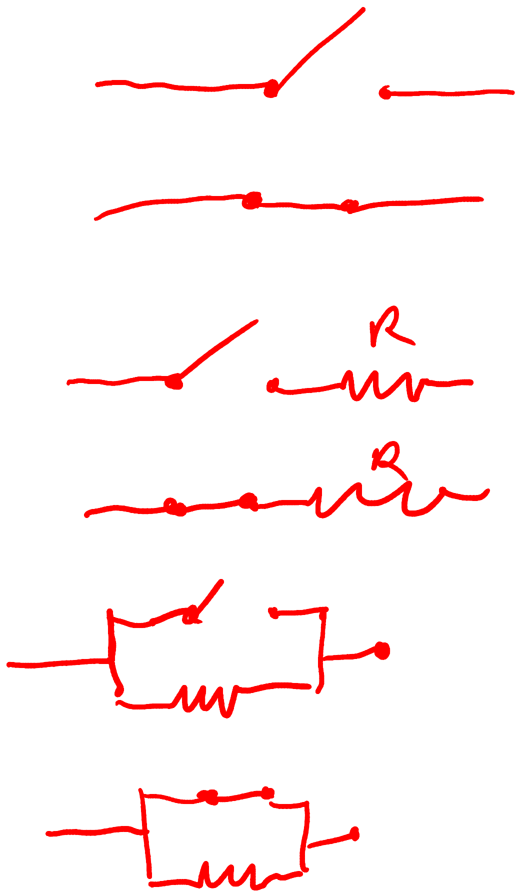
$$\frac{1}{R_{eq}} = \sum_{j=1}^{n} \frac{1}{R_j}$$



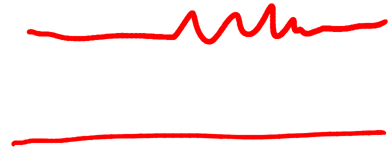
(a)
ℰ = 18 V, r = 0
4 Ω
6 Ω
3 Ω
a
c
b
1/2 = 1/6 + 1/3
(b)
18 V
4 Ω
2 Ω
a
c
b
(c)
18 V
6 Ω
a
b
(d)
18 V
6 Ω
a
b
3 A
18 V
V = IR
(e)
18 V
4 Ω
2 Ω
a
c
b
3 A
3 A
12 V
6 V
(f)
ℰ = 18 V, r = 0
6 Ω
1 A
4 Ω
3 A
3 Ω
2 A
a
c
b
12 V
6 V

Resistive Circuit Problem

Switches?



$R = \infty$



$(R = 0)$

$(\infty + R) = \infty$

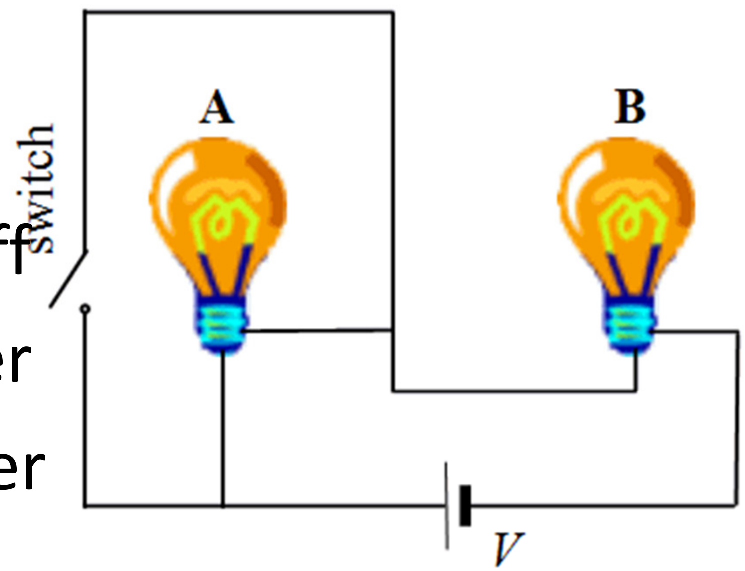
$(0 + R) = R$

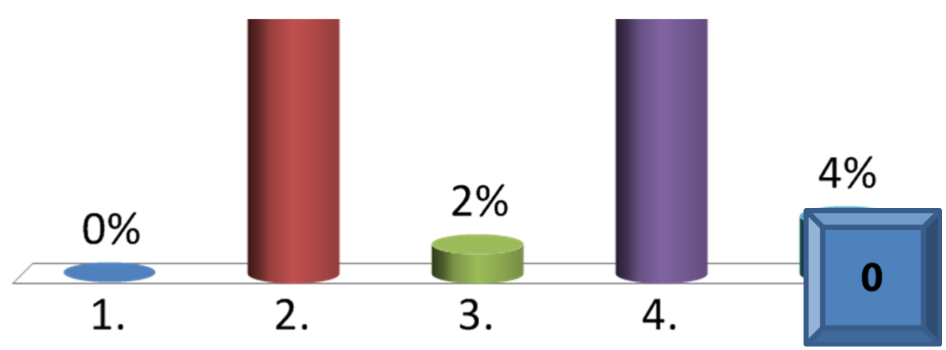
$\frac{1}{R_{eq}} = \left(\frac{1}{\infty} + \frac{1}{R} \right) = R$

$\frac{1}{R_{eq}} = \left(\frac{1}{0} + \frac{1}{R} \right) = R_{eq} = 0$

Two identical light bulbs, labeled A and B, are connected in series with a battery and are illuminated equally. There is a switch in the circuit that is initially open. Which one of the following statements concerning the two bulbs is true after the switch is closed?

1. Both bulbs will turn off.
2. No change
3. Bulb A brighter, bulb B off
4. ✓ Bulb A off, bulb B brighter
5. Both bulbs will be dimmer





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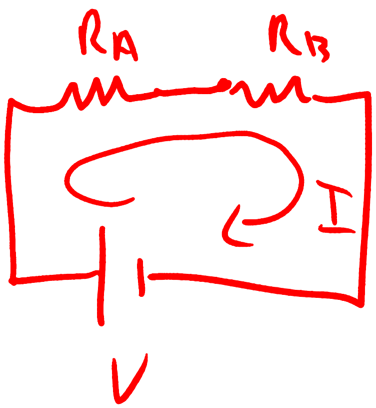
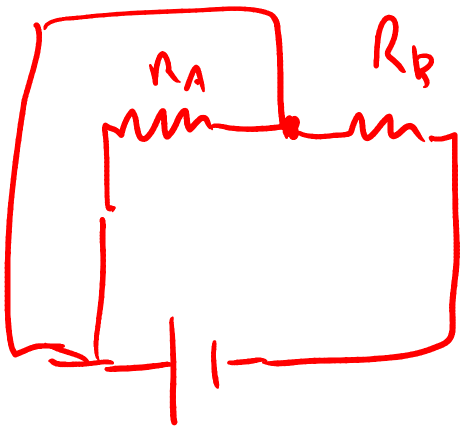
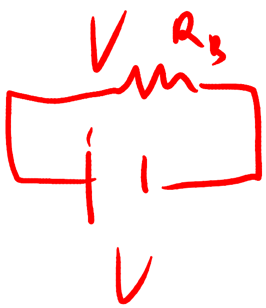
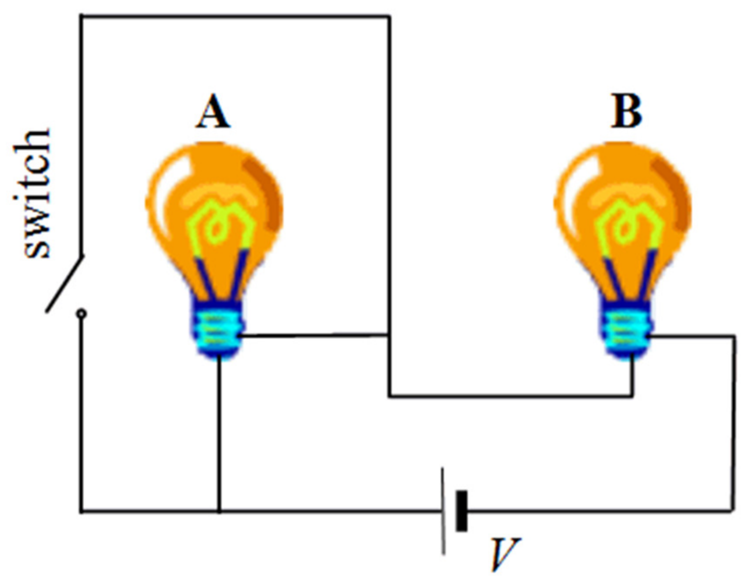
Open:



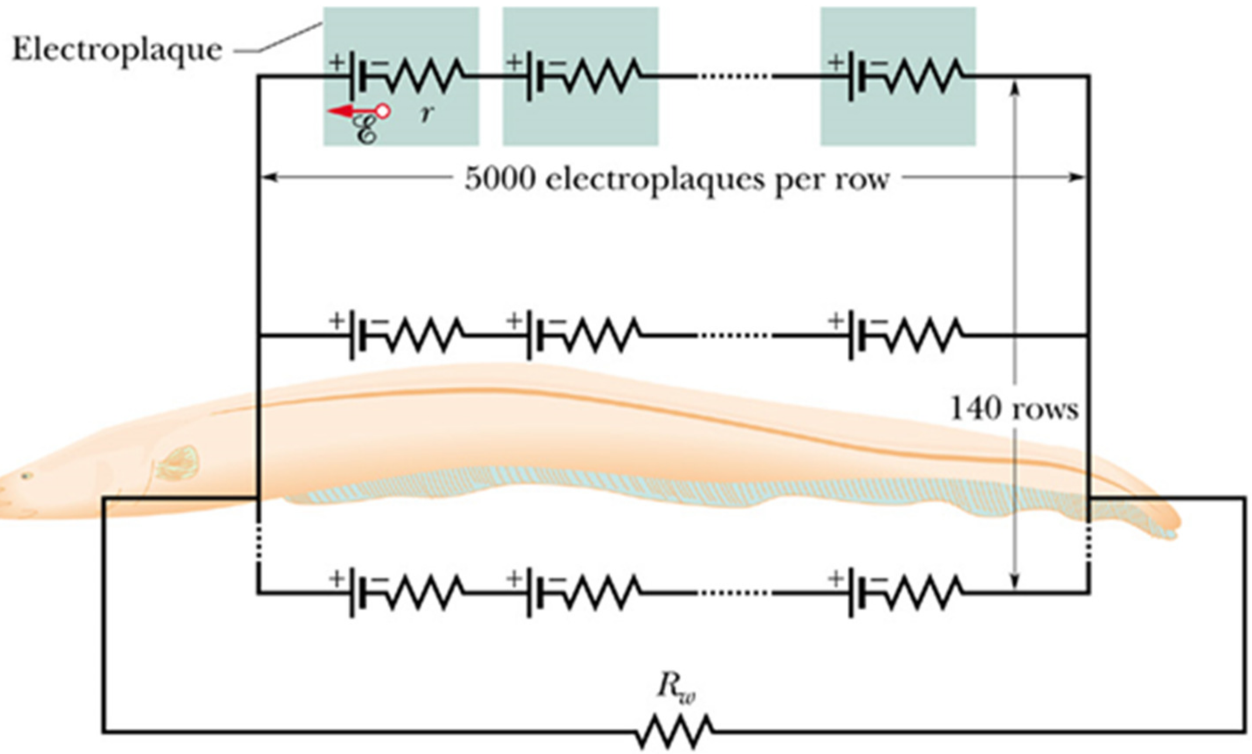
Closed:





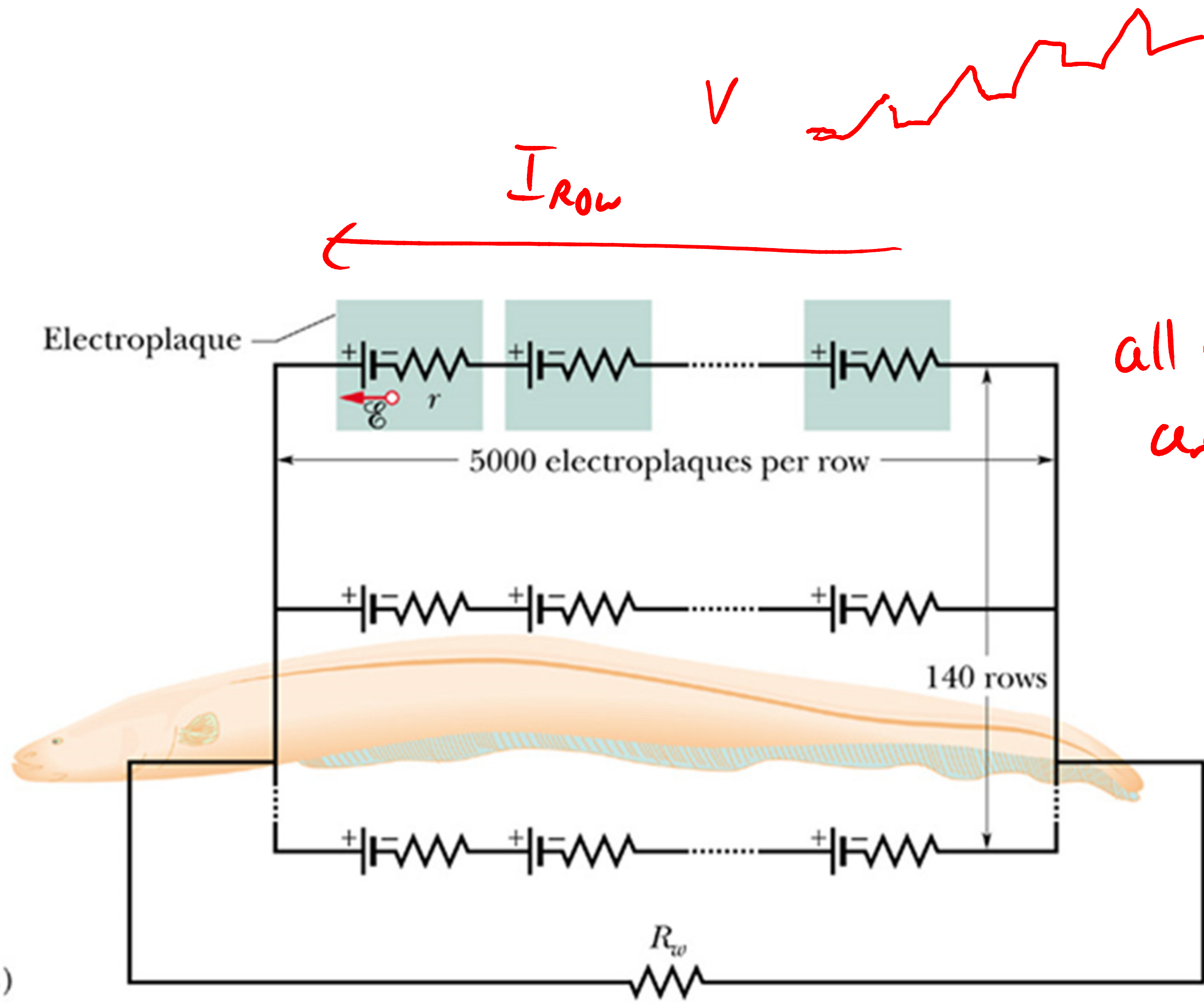


$\mathcal{E} = 0.15\ V \quad r = 0.25\ \Omega$



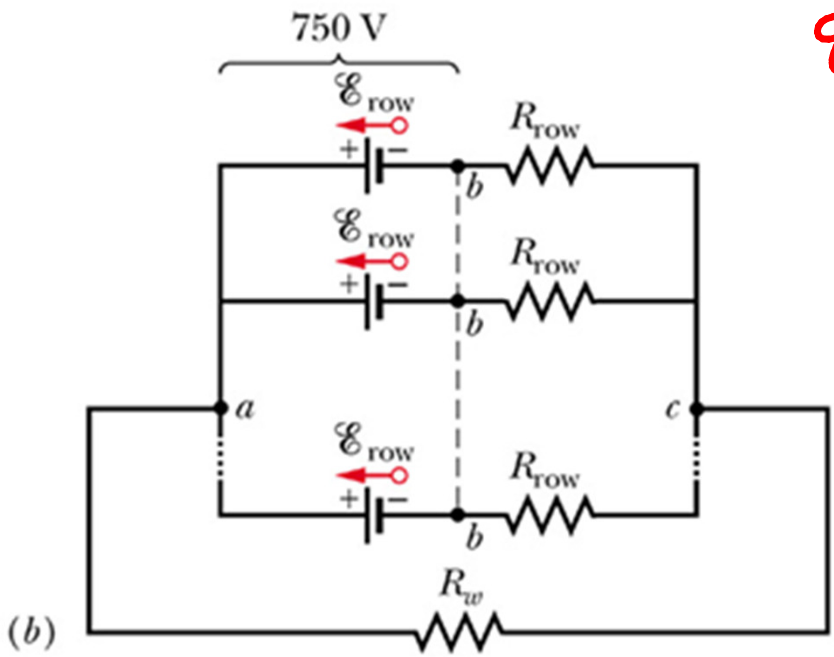
(a)

R_{water} $800\ \Omega$



(a)

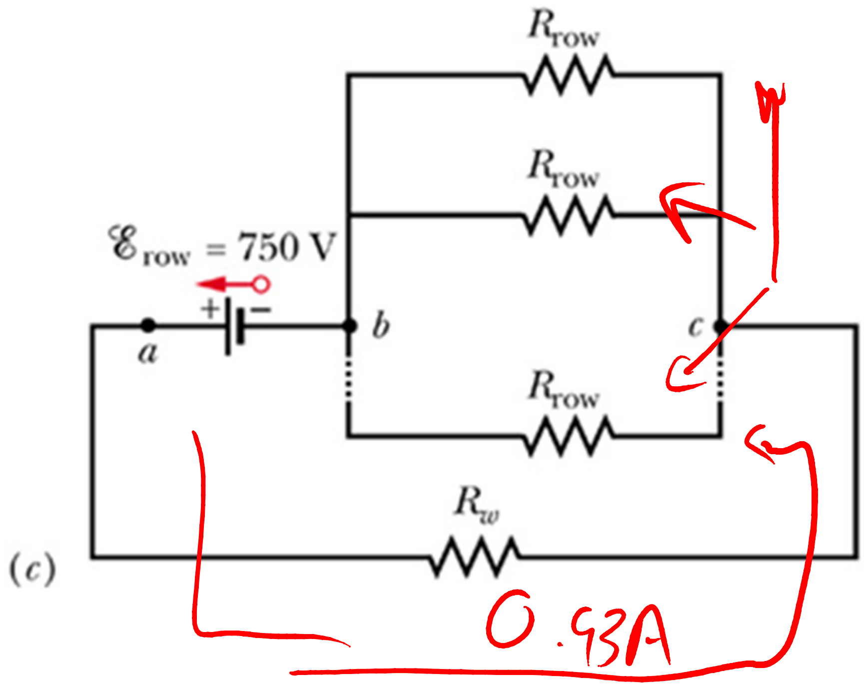
all r's in a row are in series



$$\mathcal{E}_{Row} = \mathcal{E} \cdot 5000 = 0.15\,V \cdot 5000$$

$$= 750\,V$$

$$R_{Row} = 5000 \cdot 0.25\,\Omega = 1250\,\Omega$$

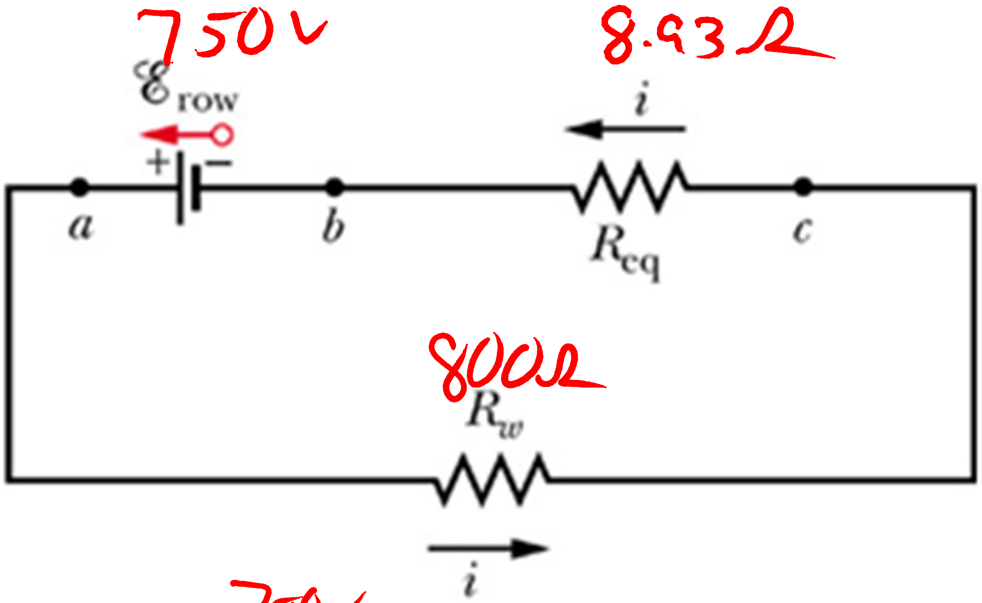


$$\frac{1}{R_{eq}} = \sum_{1}^{140} \frac{1}{R_{Row}} = 140 \frac{1}{R_{Row}}$$

$$R_{eq} = \frac{1}{140} R_{Row} = 8.93\,\Omega$$

I splits up 140 ways

$$I_{Row} = \frac{0.93\,A}{140} = 6.6\ mA$$



(d)

$$R_{eq} = 808.93\,\Omega$$

$$I = \frac{750\,V}{808.93\,\Omega} = 0.93\,A$$

$P = VI \quad I = \frac{60}{120} = 0.5A$

Some 60W light bulbs are connected in parallel to a 120 V source. Fuse F burns out at 9 A. How many bulbs can you hook up before burning out the fuse?

1. 9
2. 17 ✓
3. 25
4. 34
5. 36