Physics of Astronomy Spring - EM
Wk 3 HW due Tues 25 Apr 06 - E&Z

Ch 25 # 1, 3, 5, 7, 9, 10, 39, 75,

Sections 25–2 and 25–3

1. (I) A current of 1.50 A flows in a wire. How many electrons are flowing past any point in the wire per second? The charge on one electron is 1.60×10^{-19} C.

2. (I) A service station charges a battery using a current of 5.7 A for 7.0 h. How much charge passes through the battery?

3. (I) What is the current in amperes if 1000 Na^+ ions were to flow across a cell membrane in 7.5 μs? The charge on the sodium is the same as on an electron, but positive.

4. (I) What is the resistance of a toaster if 110 V produces a current of 4.2 A?

5. (I) What voltage will produce 0.25 A of current through a 3000-Ω resistor? $V = IR = \frac{3000}{4} = \underline{750}$ volts

6. (II) An electric device draws 5.50 A at 110 V. (*a*) If the voltage drops by 10 percent, what will be the current, assuming nothing else changes? (*b*) If the resistance of the device were reduced by 10 percent, what current would be drawn at 110 V?

7. (II) A 9.0-V battery is connected to a bulb whose resistance is 1.6 Ω. How many electrons leave the battery per minute?

8. (II) If a 12-V battery pushes a current of 0.50 A through a resistor, what is its resistance, and how many joules of energy does the battery lose in a minute?

9. (II) A hair dryer draws 7.5 A when plugged into a 120-V line. (*a*) What is its resistance? (*b*) How much charge passes through it in 15 min? (Assume direct current.) — a lot of current!

(1) $I = \frac{\Delta Q}{\Delta t} = \frac{Ne}{\Delta t}$

$N = \frac{\Delta t\, I}{e} = \frac{\text{sec} \cdot 1.5 \frac{\text{coul}}{\text{sec}}}{1.6 \cdot 10^{-19}\,\text{coul/electron}}$

$N \simeq \underline{10^{19}}$ electrons

(3) $I = \frac{\Delta Q}{\Delta t} = \frac{1000 \times 1.6 \times 10^{-19}\,\text{C}}{7.5 \times 10^{-6}\,\text{s}}$

$I \sim \frac{10^{3-19}}{10^{1-6}} = \underline{10^{-16+5}} = 10^{-11}$ ($\frac{\text{coul}}{\text{sec}}$ = Amp)

(7) $V = IR \rightarrow I = \frac{V}{R} = \frac{Q}{t} = \frac{Ne}{t}$

$I = \frac{9V}{1.6\Omega} \approx \frac{4\ \text{coul}}{\text{sec}} \Big| \frac{60\,\text{sec/min}}{1.6 \cdot 10^{-19}\,\text{coul/elec}}$

$I \approx \frac{2.4 \cdot 10^2}{1.6 \cdot 10^{-19}} \sim \underline{10^{21}}$ electrons/min

(9) $V = IR \rightarrow R = \frac{V}{I} = \frac{120\ \text{volts}}{7.5\ \text{A}} = \underline{16}\ \Omega$

$\Delta Q = \underline{6.75 \cdot 10^3}$ coul — a lot of charge!

(b) $I = \frac{\Delta Q}{\Delta t} \rightarrow \Delta Q = I\,\Delta t = 7.5 \frac{\text{coul}}{\text{sec}} \times 15\,\text{min} \left(\frac{60\,\text{sec}}{\text{min}}\right)$

75. The Tevatron accelerator at Fermilab (Illinois) is designed to carry an 11 mA beam of protons traveling at very nearly the speed of light (3.0×10^8 m/s) around a ring 6300 ~~m in~~ R circumference. How many protons are stored in the beam?

Length of beam $L = 2\pi R$

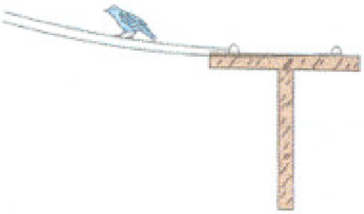
$I = \frac{\Delta Q}{\Delta t} = \left(\frac{\Delta Q}{\Delta x}\right)\frac{\Delta x}{\Delta t} = \left(\frac{Ne}{L}\right) \cdot v \rightarrow N = \frac{LI}{ev} = \frac{2\pi(6.3 \times 10^3\,\text{m})(11 \times 10^{-3}\,\frac{\text{coul}}{\text{s}})}{1.6 \cdot 10^{-19}\,\frac{\text{coul}}{\text{proton}} \times 3 \cdot 10^8\,\text{m/s}}$

$N \sim \frac{40 \cdot 10^3 \times 10^{1-3}}{5 \cdot 10^{-19+8}}$ protons

$N \sim \frac{10^1}{10^{-11}} = 10^{12}$ protons

10. (II) A bird stands on a dc electric transmission line carrying 2500 A (Fig. 25–30). The line has $2.5 \times 10^{-5}\,\Omega$ resistance per meter and the bird's feet are 4.0 cm apart. What potential difference does the bird feel?

Ch 25



2500 A is a LOT of current!

$R = \frac{dR}{dl} L = 2.5 \cdot 10^{-5}\,\Omega/m \times 4 \times 10^{-2}\,m$

$R = 10 \times 10^{-5-2} = 10^{-6}\,\Omega$

$V = IR =$

$= 2.5 \times 10^{3}\,A \times 10^{-6}\,\Omega$

$V = 2.5 \times 10^{-3}\,V$ – small potential difference.

Ch 26 Q **1.** Explain why birds can sit on power lines safely, while leaning a metal ladder up against one to fetch a stuck kite is extremely dangerous.

– small potential difference between bird feet

– metal ladder is a GOOD CONDUCTOR – can form a short circuit letting HIGH CURRENT flow to ground (and same through person holding ladder)

Ch 25

39. (II) A power station delivers 520 kW of power to a factory through wires of total resistance of 3.0 Ω. How much less power is wasted if the electricity is delivered at 50,000 V rather than 12,000 V?

$P = VI = (IR)I = I^2 R$

$P_{lost} = I^2 R$

How much current is carried in each case? $P = IV \rightarrow I = \frac{P}{V}$

$I_{high\ voltage} = \frac{P}{V_{high}} = I_{low} = \frac{520\ kW}{50\ kV} = 10.4\ A$

$P_{loss\ at\ high\ voltage} = I_{low}^2 R = 0.32\ kW$

$I_{low\ voltage} = \frac{P}{V_{low}} = I_{high} = \frac{520\ kW}{12\ kV} = 43\ A$

$P_{lost\ at\ low\ voltage} = I_{high}^2 R = 5.6\ kW$

HIGH VOLTAGE
LOW CURRENT
LOW POWER LOSS
GOOD ✓

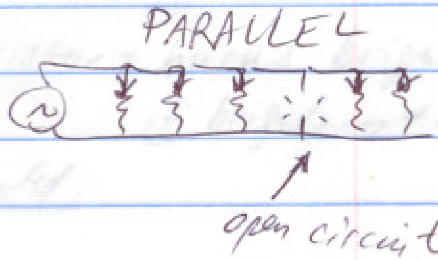
~ 20× more power is wasted at ~4× lower voltage

QUESTIONS 1, 2, 3, 4, 6, 7

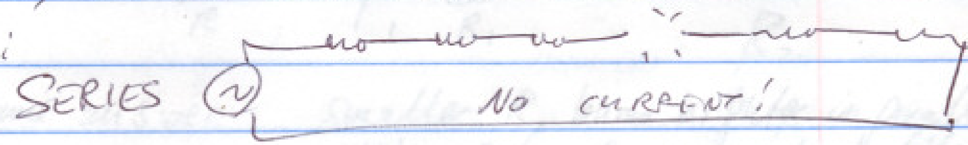
G26 2. Discuss the advantages and disadvantages of Christmas tree lights connected in parallel versus those connected in series.

3. If all you have is a 120-V line, would it be possible to light several 6-V lamps without burning them out? How?

(2) Xmas tree lights in parallel stay lit if one dies

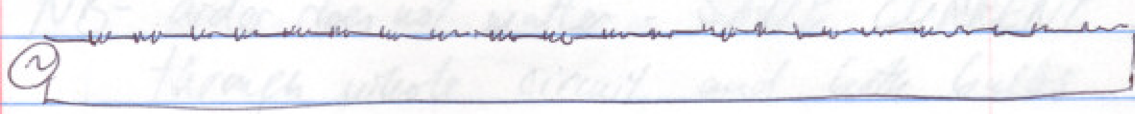


In series, one bad bulb breaks the current to the rest:

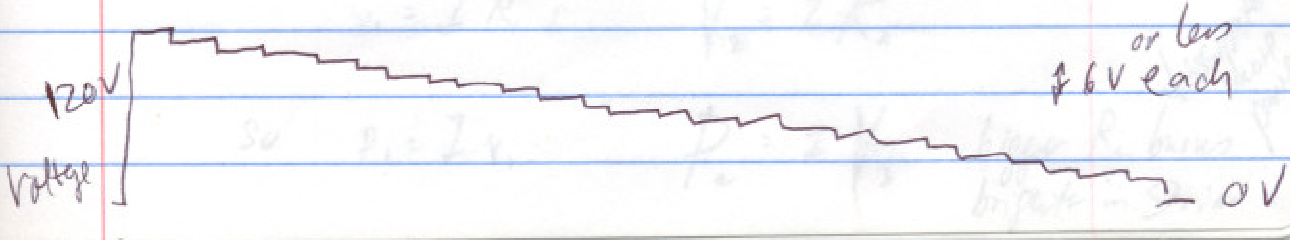


(3). NOT IN PARALLEL, or each lamp gets the whole ΔV.

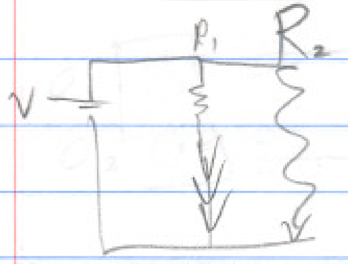
Put them in series, so the voltage drops over each lamp



$\frac{120}{6} = 20$ - you need at least 20 lamps



4. Two lightbulbs of resistance R_1 and R_2 ($>R_1$) are connected in series. Which is brighter? What if they are connected in parallel?



SAME VOLTAGE across both: $V = IR$

Different currents $I = \frac{V}{R}$

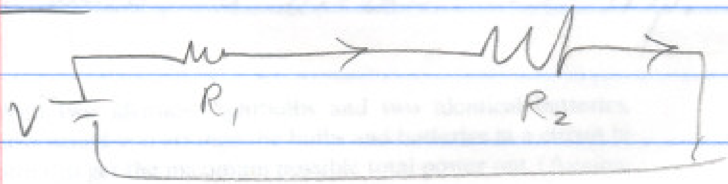
PARALLEL $I_1 = \frac{V}{R_1}$ $I_2 = \frac{V}{R_2}$

Bigger current in smaller resistor - burns brighter, *if* brightness ∝ current.

But brightness ∝ power dissipated:

$P = I^2 R = IV = \frac{V^2}{R}$; $P_1 = \frac{V^2}{R_1}$ $P_2 = \frac{V^2}{R_2}$

Same answer: smaller R, burns brighter in parallel
EASIER path for current to follow



SERIES

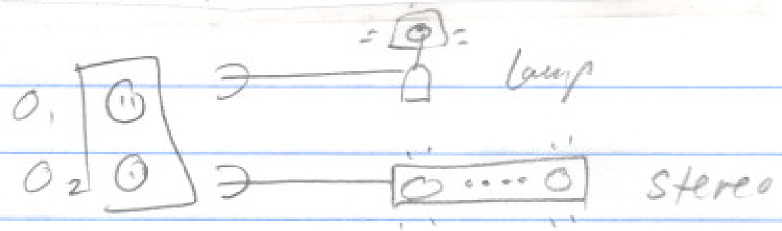
NB - order does not matter - SAME CURRENT I through whole circuit and both bulbs.

$P = IV$ - same for both bulbs? NO, because V varies:

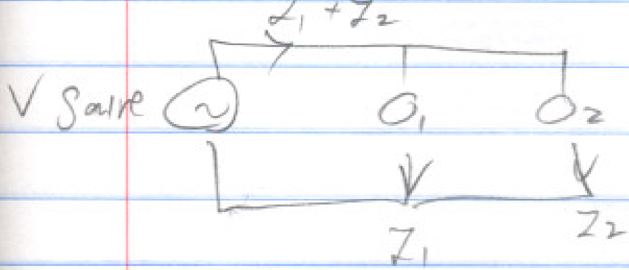
$V_1 = IR_1$, $V_2 = IR_2$

So $P_1 = IV_1$ $P_2 = IV_2$; bigger R_2 burns brighter in Series dissipates more power

6. Household outlets are often double outlets. Are these connected in series or parallel? How do you know?



Both appliances need the same voltage, so outlets need to be in PARALLEL

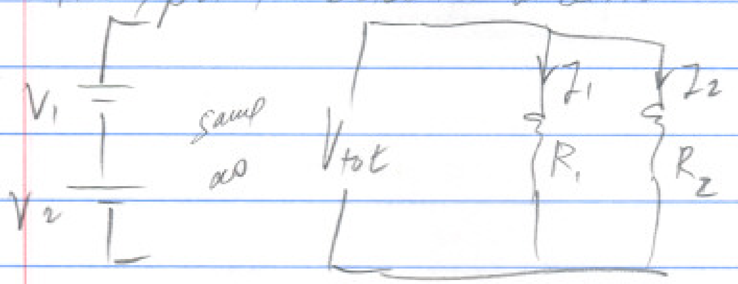


same V across both

They will try to draw as much current as they need from the power source. If it's too much current, a breaker will trip.

7. With two identical lightbulbs and two identical batteries, how would you arrange the bulbs and batteries in a circuit in order to get the maximum possible total power out. (Assume that the batteries have negligible internal resistance.)

First, put the batteries in series so $V_{tot} = V_1 + V_2$



Then put resistors in parallel to draw the maximum current.