Problem Set 10
Physics, summer 2020/21

1) **(2p.)** What is the current involved when a truck battery sets in motion 720 C of charge in 4.00 s while starting an engine?

Answer:
We can use the definition of current in the equation $I=\Delta Q/\Delta t$ to find the current, since charge and time are given.

Solution
Entering the given values for charge and time into the definition of current gives,

$$I = \frac{\Delta Q}{\Delta t} = \frac{720\ C}{4.00 s} = 180 \frac{C}{s} = 180\ A$$

This large value for current illustrates the fact that a large charge is moved in a small amount of time. The currents in these "starter motors" are fairly large because large frictional forces need to be overcome when setting something in motion.

2) **(2p)** How long does it take 1.00 C of charge to flow through a handheld calculator if a 0.300 mA current is flowing?

Answer:
Here we rearrange the definition of current and use the given values of charge and current to find the time required..

Solution
Solving the relationship $I=\Delta Q/\Delta t$ for time Δt, and entering the known values for charge and current gives,

$$\Delta t = \frac{\Delta Q}{\mathrm{I}} = \frac{1.00\ C}{0.300 \times 10^{-3} C/s} = 3.33 \times 10^{3} s$$

This time is slightly less than an hour. The small current used by the hand-held calculator takes a much longer time to move a smaller charge than the large current of the truck starter. So why can we operate our calculators only seconds after turning them on? It's because calculators require very little energy. Such small current and energy demands allow handheld calculators to operate from solar cells or to get many hours of use out of small batteries. Remember, calculators do not have moving parts in the same way that a truck engine has with cylinders and pistons, so the technology requires smaller currents.

3) **(2p.)** What is the resistance of an automobile headlight through which 2.50 A flows when 12.0 V is applied to it?

Answer:

We can rearrange Ohm's law as stated by $I=V/R$ and use it to find the resistance.

Solution

Entering the given values for charge and time into the definition of current gives,

$$R = \frac{\mathrm{U}}{\mathrm{I}} = \frac{12\ V}{2.5\ A} = 4.8\ \Omega$$

This is a relatively small resistance, but it is larger than the cold resistance of the headlight. Resistance usually increases with temperature, and so the bulb has a lower resistance when it is first switched on and will draw considerably more current during its brief warm-up period.

4) **(3p.)** A car headlight filament is made of tungsten and has a cold resistance of 0.350 Ω. If the filament is a cylinder 4.00 cm long (it may be coiled to save space), what is its diameter?

Answer:

We can rearrange the equation $R=\rho L/A$ to find the cross-sectional area A of the filament from the given information. Then its diameter can be found by assuming it has a circular cross-section.

Solution

The cross-sectional area, found by rearranging the expression for the resistance of a cylinder given in $R=\rho L/A$, is

$$A = \frac{\rho L}{\mathrm{R}} = \frac{(5.6 \times 10^8\ \Omega m)(4.0 \times 10^2 m)}{0.35\ \Omega} = 6.4 \times 10^9 m^2$$

The area of a circle is related to its diameter D by $A = \frac{\pi D^2}{4}$.

Solving for the diameter D, and substituting the value found for A, gives

$$D = 2\sqrt{\left(\frac{A}{\pi}\right)} = 2\sqrt{\left(\frac{6.4 \times 10^9}{\pi}\right)} = 9.0 \times 10^5 m$$

The diameter is just under a tenth of a millimeter. It is quoted to only two digits, because ρ is known to only two digits.

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8.05.2021r.