386.

Problem 32.13 (RHK)

We have to calculate the time that electrons take to get from a car battery to the starting motor. We may assume that the current is 115 A *and electrons travel through copper wire with cross-sectional area* 31.2 mm^2 *and length* 85.5 cm.

Solution:

In copper on an average there is nearly one conduction electron per atom.

The density of copper, $\rho_{Cu} = 8.96 \times 10^3$ kg m^{-3}.

The molar mass of copper, $M_{Cu} = 63.5 \times 10^{-3}$ kg mol^{-1}.

Let the number of electrons per cubic meter in copper metal be *n*. Then, we have

$$\frac{n}{N_A} = \frac{\rho_{Cu}}{M_{Cu}},$$

where N_A is the Avogadro number. We find

$$n = \frac{6.02 \times 10^{23} \times 8.96 \times 10^3}{63.5 \times 10^{-3}} \text{ electrons m}^{-3}$$

$$= 8.49 \times 10^{28} \text{ electrons m}^{-3}.$$

Let the drift speed of the electrons in the copper wire be v_d. Then from the definition of current that it is the charge flow through the wire per second, we have

$i = Av_d ne,$

where A is the cross-sectional area of the wire and n is the number of conduction electrons per unit volume. Therefore, from the data of the problem we calculate the drift speed v_d. It will be

$$v_d = \frac{i}{Ane} = \frac{115}{31.2\times10^{-6}\times8.49\times10^{28}\times1.6\times10^{-19}} \text{ m s}^{-1}$$
$$= 0.27\times10^{-3} \text{ m s}^{-1}.$$

Length of the copper wire from the connecting battery to the motor is 85.5 cm. Therefore, the time that electrons will take in reaching the motor from the car battery will be

$$t = \frac{0.855}{0.271\times10^{-3}\times60} \text{ minutes} = 52.5 \text{ minutes.}$$