## *E.3 Voltage*

When a charge passes through a battery it is given electrical energy. When it passes around a circuit it transfers this electrical energy to the circuit elements (perhaps a light globe).
The term voltage is used to refer to the amount of energy that is given to a charge or is used up by a charge when moving around a circuit.
The voltage of a battery refers to how many joules are given to each coulomb of charge:

$$1\ \text{V} = 1\ \text{J C}^{-1}$$

$$voltage = \frac{energy}{charge}$$

In this case the energy is in the form of electrical energy.

$$\therefore \quad V = \frac{E}{q}$$

Voltage is sometimes referred to as potential difference, the difference in potential energy of a charge at two different places in a circuit or EMF (electromotive force).

Example
The alternator of a car being driven at night with the headlights on, is producing a 50 A current at an EMF of 12 V.

**a** How many coulombs of charge flow from the alternator each second?
**b** How many joules of energy does each coulomb of charge obtain?
**c** How many joules of energy does the alternator produce each second?
**d** Where does this energy go?

***Solution***
**a** The 50 A current means that 50 C of charge flow each second ($q = It$).
**b** The 12 V EMF means that each 1 C of charge is given 12 J of energy.
**c** Each second, 50 C of charge each with 12 J of energy flow from the alternator, so the energy produced is 50 × 12 = 600 J.
**d** This energy will go to the headlights, the ignition system and any other electrical devices in operation. Some may also be used to re-charge the battery.

Example
The potential difference across a torch bulb is found to be 2.7 V. The current flowing through it is 0.2 A.
**a** How much charge flows through the torch in 1 minute?
**b** How much energy is transferred by this charge?

***Solution***
**a** $q = It$ = 0.2 A × 60 s = 12 C
**b** Each coulomb lost 2.7 J of energy. $\Delta U = qV$ = 12 × 2.7 = 32.4 J

## *E.4 Power*

**Video: Electric Power**

The rate at which energy is supplied by a battery, or is used up in a circuit element, is called power

$$Power = \frac{energy}{time}$$

The energy supplied by a battery is voltage(V) × amount of charge(q)

$E = q\,V$ or $E = V\,I\,t$

$$Power = \frac{V\,I\,t}{t}$$

$Power = V\,I$ Watt(W)

Example

How much energy is used in 1 h by a 240 V heater drawing 5 A?

***Solution***
Each coulomb of charge gives 240 J of heat energy, and in 1 h the number of coulombs used is given by $q$ = 5 A × 3600 s.
The total energy used is thus $E = VIt$ = 240 × 5 × 3600 = 4.3 × 106 J = 4.3 MJ.

Example

Two different torch bulbs are rated as 2.8 V, 0.27 A, and 4.2 V, 0.18 A.
**a** Which will be the brightest?
**b** Could they be interchanged?

***Solution***
**a** The brightness is indicated by the power used. $P = VI$ and so their powers are 2.8 × 0.27 = 0.76 W (or 760 mW) and 4.2 × 0.18 = 0.76 W. The bulbs will be the same brightness.

**b** Although the power of each bulb is similar, using them in the wrong torch will either result in the bulb burning out or running dim. The bulbs are designed to work at a certain voltage. If a greater voltage is used, too much current will flow in the bulb which will result in it burning out.

### *E.4.1 Alternative unit for Energy*

When we pay for our electricity we pay for the energy used.

The energy is calculated using:

$$E = P\,t$$

The unit used by the electricity companies is kilowatt hour (kWh).

The unit for electrical energy is the joule. In industry and in household consumption of electricity the unit kilowatt hour (kWh) is used. One kWh is the energy delivered in one hour at a rate of 1000 W.

$\Rightarrow$ 1 kWh = 1000 × 3600 s

$\Rightarrow$ = $3.6 \times 10^6$ J

Example

At a rate of 15 cents per kWh, how much will it cost to run a 200 W television for 4 hours per day for a week?

Solution

$$E = P\,t$$
$$E = 200 \times 4$$
$$E = 800\ Wh$$
$$E = 0.8\ kWh \text{ each day}$$
$$E = 0.8 \times 7 = 5.6\ kWh \text{ per week}$$

$$Cost = 5.6 \times 15 = 84\ cents$$

**Problem Set #3:** Text Section 3.3 Page 109 Questions 1 – 6
Text Section 4.3 Page 157 Questions 3, 4