Chapter 7 Notes: Electrical Power

How much energy is supplied by the battery *each second*?

The whole idea behind constructing electrical circuits in the first place is to use electrical energy for some useful purpose, e.g. lighting a light bulb, turning a motor, heating a room, etc. ***Question:*** *Identical light bulbs A and B are hooked up to batteries in different circuits. Given that PE transferred by the current to bulb A in the first circuit is 5 J, while PE transferred by the current in the second circuit to bulb B is 10 J, can one say that (a) bulb A is brighter than bulb B; (b) bulb B is brighter than bulb A; (c) bulbs A and B are the same brightness, or (d) there is not enough information to determine which is brighter.* ***Answer:*** *(d), there is not enough information.* Suppose that the 5 J was supplied to bulb A in 0.01 s, while the 10 J was supplied to bulb B over a period of 10 s. Bulb A might burn brightly – but very briefly – just as if it were a flashbulb. Meantime, bulb B might not glow visibly at all. The ***rate of use of energy*** – the ratio of [energy transferred ÷ elapsed time] – is an important quantity when dealing with practical applications of electrical energy. This ratio is called ***power*** (symbol: *P*). In the case of electrical currents, the *KE* of the charges is essentially constant, so we will use $P = \Delta PE \div \Delta t$. The unit of power is called the watt (symbol: W). 1 W = 1 J/s. That is, one joule of energy supplied every second is equivalent to a power consumption of one watt (1 Ws = 1 J). A common unit of energy is the kilowatt-hour (kWh): 1 kWh is the amount of energy transferred when 1000 W of power is supplied for one hour. 1 kWh = 1000 Wh = 3.6×10^6 J.

Now, how can we figure out the power supplied by a battery in a particular circuit? First, let's consider the potential energy supplied by the battery to a particular quantity of charge – call this quantity Δq – as it flows through the battery from the negative terminal to the positive terminal. Then the change in potential energy of the charge will be given by $\Delta PE = (\Delta q) \times (\Delta V)$, where ΔV is the potential difference between the battery terminals. Then the power supplied by the battery is given by the following relationship:

$$P = \frac{\Delta PE}{\Delta t} = \frac{(\Delta q)(\Delta V)}{\Delta t} = (\frac{\Delta q}{\Delta t})\Delta V = I\Delta V$$

Here we have made use of the definition of electrical current, $I = \Delta q \div \Delta t$. So we can now see that the power supplied by the battery is equal to the [amount of current flowing through the battery] multiplied by the [battery voltage]. We will always use the symbol "I_{tot}" to refer to the amount of current flowing through the battery, and P_{bat} to refer to the power supplied by the battery. This gives us our first important relationship involving electrical power: $P_{bat} = I_{tot}\Delta V_{bat}$

In the case of power "dissipated" by a resistor (that is, the rate of energy transfer by the current to the resistor), we know that there will be a loss of *PE* by the current as it flows through the resistor. By following the same line of reasoning as described above for the case of the battery, we can obtain a very similar relationship for power dissipated in a resistor with resistance *R*: $P_R = I_R \Delta V_R$ This equation says that the power supplied to a particular resistor is given by the product of the current flowing ***through that resistor*** and the potential drop ***across that resistor***. By using Ohm's law [$I_R = \Delta V_R \div R$], we can obtain two other forms of that same relationship:

$$(1)\ P_R = I_R^2 R \qquad (2)\ P_R = \frac{(\Delta V_R)^2}{R}$$

It is ***extremely important,*** when considering the power dissipated in a resistor, to use the *I*, *R*, and the ΔV for ***that particular resistor only***, and not, for instance, the values referring to the battery, or to some other resistor.

These last two equations can only be applied to the power supplied by the battery when the quantity $R_{equivalent}$ is used for the resistance. (The equivalent resistance $R_{equivalent}$ will be discussed in more detail in Chapter 8). In that case we will have the following relationships: (1) $P_{bat} = I_{tot}^2 R_{equiv}$ (2) $P_{bat} = \frac{(\Delta V_{bat})^2}{R_{equiv}}$