Student Notes

Mechanical Potential Energy

Let's take a look a situation where someone is holding a book above a table as shown in figure 1. The mechanical potential energy of this book is defined as:

$$W = Fd$$

Where W is the symbol for energy, F is the force (or the weight of the book) and d is the distance from the book to the table. For example if the book weighs 5 lbs (F =5) and the distance is 4 ft (d = 4), then the potential energy, W, is 20 ft-lbs. Actually the potential energy, W, is defined to be the distance from the book (B) to the desk (D). We can now express the potential energy from the book to the desk as W_{BD} (The energy from B to D). Note that it takes two points to define a potential energy.

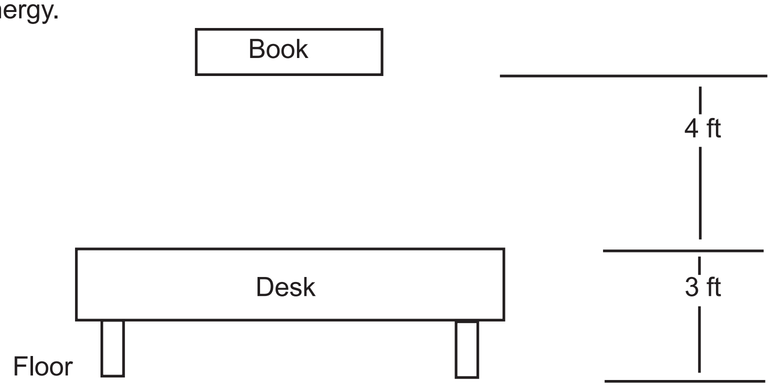

Fig. 1

Please note that we also have a potential energy from the book to the floor (W_{BF}). Where W_{BF} is equal to (5 lbs)*(7 ft) = 35 ft-lbs. Likewise, if we place the book on the desk we now have W_{DF} (The energy from the Desk to the floor) equal to

(5 lbs)*(3 ft) = 15 ft-lbs.

What about the case where the book is on the floor and someone picks it up and places it on the desk? Now, because the book is taking the potential energy from some person, we say that W_{FB} is equal to – 15 ft-lbs. Note that W_{BF} is equal to -W_{FB}. If the potential energy is a positive number this indicates that when dropped, the book will impart energy, or do work, on the object it hits. If the potential energy is a negative number, then the book is taking energy from some external source (or the external source is doing work on the book).

We now are able to see the occurrence of a law of nature that states:

"The sum of the potential energy around any closed loop is equal to zero"

Student Notes

Example problem number 1

Use figure 1 to illustrate the law of nature that states "The sum of the potential energy around any closed loop is equal to zero".

Solution:

The potential energy from the floor (F) to the book (B) to the desk (D) and back to the floor (F) constitutes a closed loop. Mathematically stated we have:

$$W_{FB} + W_{BD} + W_{DF} = 0 \qquad \text{Eq 1}$$

$$-35 \text{ ft-lbs} + 20 \text{ ft-lbs} + 15 \text{ ft-lbs} = 0$$

Electrical Potential Energy

Electrical potential energy is usually referred to as voltage. However some scientist, such as physicists and chemists, simply refer to it as "potential", or "electric potential". The symbol for voltage is V. Voltages, also know as voltage sources, can be produced by:

- Batteries (Chemical reactions)
- Generators/Alternators (electromagnetic induction)
- Solar cells (photo-voltaic)

Voltage sources are also known as the Electro-Motive forces, or EMF.

Like mechanical potential energy, electric potential energy also needs two points to determine its definition. For example, the AA battery shown in figure 2 illustrates that chemical reactions have formed some positive (+) charges at the battery anode (A) and some negative (-) charges at the battery cathode (-). Hence the voltage from the anode to cathode is:

V_{AC} = 1.5 Volts

Just like mechanical potential energy, we can say that the voltage from cathode to anode is:

V_{CA} = -1.5 Volts.

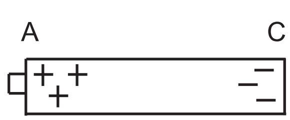

Fig. 2

Student Notes

The schematic representation of the AA battery, or of any voltage source, is shown in figure 3.

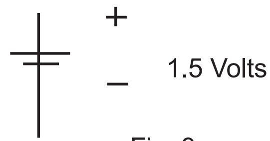

Fig. 3

A special meter that has been designed to measure the electrical potential energy is called a voltmeter. It takes two points to measure a voltage so the meter is equipped with two color coded wires, called leads. The red lead is connected to the VW terminal of the meter and the black lead is connected to the COM terminal of the meter. If we were to connect a voltmeter to the battery terminals A ,C of figure 3, the display would read 1.50 volts. (V_{AC} = 1.5 volts) That is, the red lead has to be connected to terminal A and the black lead needs to be connected to terminal C. On the other hand if the read lead was connected to battery terminal C and the black lead was connected to battery terminal A, the voltmeter would read – 1.50 volts. (V_{CA} = - 1.5 volts) Figure 4a illustrates the proper connection of a voltmeter when measuring the voltage V_{AC}. Figure 4a illustrates the proper connection of a voltmeter when measuring the voltage V_{CA}.

Fig. 4a

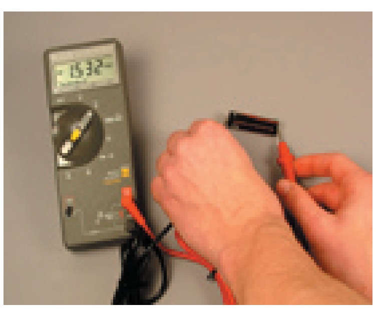

Fig. 4b

In 1847, Gustav Robert Kirchhoff transferred the concept of mechanical potential energy to electric potential energy. This law of physics has become known as Kirchhoff's voltage law, or simply KVL. We can demonstrate KVL by analyzing the circuit shown in figure 5. Here we have two batteries, a 9-volt and a 1.5 volt battery. Note that wire A is connected to the anode of the 9 volt battery and wire B is connected from the cathode of the 9 volt battery to the cathode of the 1.5 volt battery. Wire C is connected to the anode of the 1.5 volt battery. If the read lead were connected to wires C and the black to wire B the meter would measure 7.5 volts. How do we know this? We apply the mechanical potential energy rule of equation 1 to figure 5. Here we have:

Student Notes

$V_{AC} + V_{CB} + V_{BA} = 0$ Eq 2

$V_{AC} + 1.5 - 9.0 = 0$

$V_{AC} = 9.0 - 1.5 = 7.5$ volts

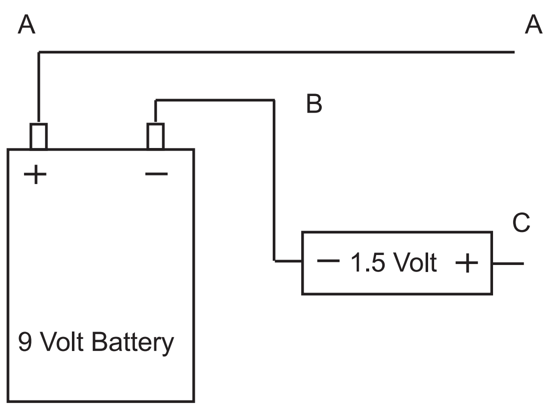

Fig. 5

Equation 2 is an example of KVL. The total voltage around any closed loop is equal to zero. The loop starts at wire A, goes to wire C, then to wire B and back to wire A, thus making a closed loop. If the voltmeter were connected to wires A and C, it would read 7.5 volts. We say that the polarity of the two batteries appose each other.

The schematic diagram of the circuit shown in figure 5 is shown in figure 6.

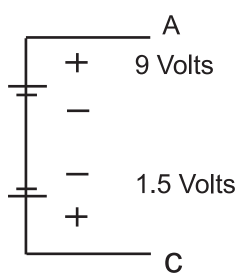

Figure 6