Unit 4 Energy Conservation

Unit Overview

This unit is designed to introduce the concept of energy conservation. Initially, the topic will be developed in stages: work, gravitational energy, kinetic energy, elastic energy. Work will be introduced as a defined quantity while energy will be developed as the ability to do work. After the students have become proficient at calculating work and energy, they will then begin to understand energy, its conservation and the application of energy conservation to problem solving. After establishing the concept of energy conservation, the students will then apply this concept to simple machines, heat engines, universal gravitation and the formation of black holes.

Lesson 4:1 Introduction to Work & Energy

Objective(s):

- To introduce the concept of work by comparing and contrasting the idea of work in the physics sense to our every day understanding of work.
- To introduce the work done in moving an object against the gravitational force.
- To introduce the concept of power as the rate of doing work.

Skills attained:

- The students will be able to calculate the work done by a constant force.
- The students will be able to calculate power based both on work done per unit time and the product of force and velocity.
- The students will be able to calculate the work done against the gravitational force.
- The students will recognize the appropriate MKS units for work [Joule] and power [Watt] as well as their fundamental MKS equivalents [Joule = $kg \cong m^2/s^2$ and Watt = $kg \cong m^2/s^3$].

Topics Addressed:

- Definition of work – Work = Force ≅ distance ≅ cos(α)
- Calculation of work
- Calculation of power – Power = Work/time = Force ≅ distance/time = Force ≅ velocity

Materials list: friction block [or equivalent such as a crate full of masses], spring scale, string or rope, kilogram mass, inclined plane & protractor.

Class Preparation:

- Collect all of the materials in the **Materials list**

- Prepare a "sled" by attaching a string or rope to the front of the friction block or a crate.
- Review the *Class Notes 4:1a-b, 4:2a-b and 4:3a-c on Work, Power & Energy*.

Procedure / Suggested Teaching Strategies:

- Return and review *Test 3:A or 3:B Newton's Laws*. If you find that a particular problem or problems on the test was missed more often than the others, it would be useful to have select students put their solutions to the problem on the board where the problems can be used as the focus of class discussion. The topic of Newton's Laws is one of the most fundamental and it is critical that you clarify any confusion that may be present before proceeding to the topic of energy conservation.
- As you complete the review of the test on Newton's Laws, the next step today will be to introduce the concepts of work, power and gravitational energy. To this end refer to the *Class Notes 4:1a-b Work & Power*, *4:2a-b Work – Problem Solving* and *4:3a-c Gravitational Potential Energy*.
- During your lecture demonstrate work is various ways such as
  - Show that no work is done when a force is applied but no motion occurs. For example push hard on the lab/demonstration table in the front of you class room and show how no work is done since no motion occurs .[Assuming, of course, that the lab/demonstration table is attached to the floor.]
  - Show that in the absence of an external force no work is required to keep the object in motion. Give a initial push to a rolling object on a horizontal surface and note that the velocity remains basically constant after the removal of the external force. [I use a bowling ball! One of my most useful pieces of apparatus.]
  - Pull a block across the lab/demonstration table by a string or rope tied to the front end of the block. First pull the block horizontally and point out the work being done and then pull the string/rope at an upward angle and point out how the angle between the string or rope and the table's surface is incorporated into the calculation of work.
  - By comparison illustrate the is pulling the friction block up an inclined plane the angle of the incline is NOT the angle in the calculation for work since the force used to pull the block up the incline is parallel to the displacement of the block.
  - Use a spring scale lift a 1.0 kg mass from the floor to the table top and show how the work done is equal to the weight of the mass and the height of the table.

Special Considerations: Emphasize that for work to occur both a force and a displacement must be present and that the force is the cause of the displacement!

Lecture Support: *Class Notes 4:1a-b Work & Power*, *4:2a-b Problem Solving* and *4:3a-c Gravitational Potential Energy GPE*

Assessment: none

Homework Assignment: *HW 4:1 #1-6 Work* and *HW 4:1 #7-9 GPE*

Lesson 4:2 Kinetic Energy, Hooke's Law & Elastic Potential Energy

Objective(s):

- To introduce the concepts of kinetic and elastic potential energies.
- To introduce Hooke's Law.
- To introduce the concept of energy conservation.

Skills attained:

- The students will be able to calculate the kinetic energy of a moving object.
- The students will be able to calculate the energy stored in a spring.
- The students will understand how to calculate the work done by a force by calculating the area under a graph comparing the force applied to the displacement of the object.
- The students will be able to determine the equation that represents Hooke's Law from a graph plotting force vs. displacement.

Topics Addressed: kinetic energy, elastic potential energy, area under a force-displacement graph, Hooke's Law

Materials list: spring hanging from either the ceiling or a ring stand, mass set, meterstick, hammer, board & nail, spring scale.

Class Preparation:

- Collect **Materials list** for demonstrations.
- Attach a hook to the ceiling of the classroom to attach the spring.
- For the springs, use one of the 1″ diameter slinky's cut into 20-30 cm lengths and then bend a hook in each end of the springs. Cut enough springs for use in the lab on Hooke's Law. It is not necessary for the springs to be exactly the same length. In fact, it would be better if they were different so that each lab group will have a slightly different spring constant. [The spring constant is inversely proportional to the length of the spring.]

Procedure / Suggested Teaching Strategies:

- The first step today will be to review *HW 4:1 #1-6 Work* and *HW 4:1 #7-9 GPE*. These are pretty easy problems and there shouldn't be any major problem. The only minor difficulty is to note that the GPE depends only on the height of the stairway and not upon its depth.
- The next step today will be to introduce kinetic energy. The emphasis here is that work done by a moving object depends on the square of the object's velocity. Going through Class Notes 4:4 will connect kinetic energy KE to gravitational potential energy by making use of the concept of energy conservation. At this point, however, the idea of energy conservation is being used but is not yet the focus of the class. Elicit from the class examples where something is able to do work because of its

motion. Many possible examples include: car crashes, pile drivers, hydroelectric power, hammer, football blockers, etc.

- After kinetic energy your next step will be to introduce Hooke's Law. For this you want to have a spring and weight set available. The spring should either be mounted on a tall ring stand [the equipment to be used in the lab would be appropriate] or it should be suspended from a string attached to a hook in the ceiling. Vary the weight and illustrate how changing the weight affects that the spring has been stretched. Leave it to the lab to actually plot out the effect. *Class Notes 4:5a-c* help point out the relationship between force and the change in length of a spring.
- After demonstrating Hooke's Law, the next step will be to show how the area under a force vs. displacement graph leads to work done and then use this idea to develop the equation for elastic potential energy. See *Class Notes 4:5d* for EPE from Hooke's Law.
- Assign *HW 4:1 #10-14* on kinetic energy and *HW 4:1 #15-18* covering Hooke's Law and elastic potential energy.

Special Considerations: Remember to emphasize the connection between all of the different energy types to the work that they can perform.

Lecture Support: Class Notes 4:4 Kinetic Energy and 4:5a-d Hooke's Law & EPE

Assessment: *Quiz 3:2 Force of Friction* [Allow 15 min.]

Homework Assignment: *HW 4:1 #10-14 KE* and *HW 4:1 #15-18 Hooke's Law & EPE*

Lesson 4:3 Energy Conservation

Objective(s):

- To develop the factors that determine whether a system is opened or closed.
- To introduce the concept of energy conservation in a closed system.
- To demonstrate the conservation of energy using both a mass on the end of a spring and a simple pendulum.

Skills attained: The students will

- begin to appreciate the importance of a closed system when using the conservation of energy.
- begin to understand that in a closed system the total energy can convert from one form into another while the total energy in the system remains constant.
- be able to calculate the total energy content at various points in a closed system that includes kinetic, gravitational and elastic energies.
- become aware that work done by an outside force is the only way to change the total energy content of a closed system. [the Work-Energy theorem]