Unit 4: Newtonian Mechanics – Energy

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OBJECTIVES

We will continue to reinforce the all topics explored previously.

Big Idea 2: Fields existing in space can be used to explain interactions.

Essential Understanding 2.E: Physicists often construct a map of isolines connecting points of equal value for some quantity related to a field and use these maps to help visualize the field.

Essential Knowledge 2.E.1: Isolines on a topographic (elevation) map describe the lines of approximately equal gravitational potential energy per unit mass (gravitational equipotential.) As the distance between two different isolines decreases, the steepness of the surface increases. [Contour lines on topographic maps are useful teaching tools for introducing the concept of equipotential lines. Students are encouraged to use the analogy in their answers when explaining gravitational *end electrical potential and potential difference*.]

Learning Objective 2.E.1.1: The student is able to construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential.

Big Idea 3: The interactions of an object with other objects can be described by forces.

Enduring Understanding 3.E: A force exerted on an object can change the kinetic energy of the object.

Essential Knowledge 3.E.1: The change in the kinetic energy of an object depends on the force exerted on the object and on the displacement of the object during the time interval that the force is exerted.

a. Only the component of the net force exerted on an object parallel or antiparallel to the displacement of the object will increase (parallel) or decrease (antiparallel) the kinetic energy of the object.

b. The magnitude of the change in the kinetic energy is the product of the magnitude of the displacement and of the magnitude of the component of force parallel or antiparallel to the displacement.

c. The component of the net force exerted on an object perpendicular to the direction of the displacement of the object can change the direction of the motion of the object without changing the kinetic energy of the object. This should include uniform circular motion and projectile motion.

Learning Objective 3.E.1.1: The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.

Learning Objective 3.E.1.2: The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged.

Learning Objective 3.E.1.3: The student is able to use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged.

Learning Objective 3.E.1.4: The student is able to apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object.

Big Idea 4: Interactions between systems can result in changes in those systems.

Enduring Understanding 4.C: Interactions with other objects or systems can change the total energy of a system.

Essential Knowledge 4.C.1: The energy of a system includes its kinetic energy, potential energy, and microscopic internal energy. Examples should include gravitational potential energy, elastic potential energy, and kinetic energy.

Learning Objective 4.C.1.1: The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.

Learning Objective 4.C.1.2: The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.

Essential Knowledge 4.C.2: Mechanical energy (the sum of kinetic and potential energy) is transferred into or out of a system when an external force is exerted on a system such that a component of the force is parallel to its displacement. The process through which the energy is transferred is called work.

a. If the force is constant during a given displacement, then the work done is the product of the displacement and the component of the force parallel or antiparallel to the displacement.

b. Work (change in energy) can be found from the area under a graph of the magnitude of the force component parallel to the displacement versus displacement.

Learning Objective 4.C.2.1: The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass.

Learning Objective 4.C.2.2: The student is able to apply the concepts of conservation of energy and the work-energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system.

<u>Big Idea 5</u>: Changes that occur as a result of interactions are constrained by conservation laws.
<u>Enduring Understanding 5.A</u>: Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.

<u>Essential Knowledge 5.A.1</u>: A system is an object or a collection of objects. The objects are treated as having no internal structure.

<u>Essential Knowledge 5.A.2</u>: For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.

<u>Learning Objective 5.A.2.1</u>: The student is able to define open and closed/isolated systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.

<u>Essential Knowledge 5.A.3</u>: An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system.

<u>Essential Knowledge 5.A.4</u>: The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.

<u>Enduring Understanding 5.B</u>: The energy of a system is conserved.

<u>Essential Knowledge 5.B.1</u>: Classically, an object can only have kinetic energy since potential energy requires an interaction between two or more objects.

<u>Learning Objective 5.B.1.1</u>: The student is able to set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy.

<u>Learning Objective 5.B.1.2</u>: The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies.

<u>Essential Knowledge 5.B.2</u>: A system with internal structure can have internal energy, and changes in a system's internal structure can result in changes in internal energy. (This includes mass-spring oscillators, simple pendulums, charged objects in electric fields, and changes in internal energy when configuration changes.)

<u>Learning Objective 5.B.2.1</u>: The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.

<u>Essential Knowledge 5.B.3</u>: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
a. The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system.
b. Changes in the internal structure can result in changes in potential energy.

Learning Objective 5.B.3.1: the student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

Learning Objective 5.B.3.2: The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

Learning Objective 5.B.3.3: The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

Essential Knowledge 5.B.4: The internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system.

a. Since energy is constant in a closed system, changes in a system's potential energy can result in changes to the system's kinetic energy.

b. The changes in potential and kinetic energies in a system may be further constrained by the construction of the system.

Learning Objective 5.B.4.1: The student is able to describe and make predictions about the internal energy of systems.

Learning Objective 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system using information from representations of that system.

Essential Knowledge 5.B.5: Energy can be transferred by an external force exerted on an object or system that moves the object or system through a distance. This process is called doing work on a system. The amount of energy transferred by this mechanical process is called work. Energy transfer in mechanical or electrical systems may occur at different rates. Power is defined as the rate of energy transfer into, out of, or within a system.

Learning Objective 5.B.5.1: The student is able to **design an experiment** and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance.

Learning Objective 5.B.5.2: The student is able to **design an experiment** and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system.

Learning Objective 5.B.5.3: The student is able to predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.

Learning Objective 5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy.)

Learning Objective 5.B.5.5: The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.

PROCEDURE:

1. Phase 1: Systems and Internal Energy, including Kinetic and Potential Energies
   - Notes: Roman numeral I
2. Phase 2: Work and the Work-Energy Theorem: This one is long, so start early.
   - Notes: Roman numeral II, III, and IV
   - Homework 1: Chapter 6 Conceptual Questions 1-11 and 14 and Problems 1, 2, 4, 5, 6 (a only, but justify it!), 12, 15, 25, 26, 27, 30, 63 (a only), 65, 67, 68, 70, 80 (conceptual only), 81 (conceptual only) and 83 (conceptual only)
3. Phase 3: Conservation of Energy
   - Notes: Roman numeral V
4. Phase 4: Power
   - Notes: Roman numeral VI
   - Homework 2: (READ THE FOOTNOTES BY EACH PROBLEM...) Chapter 6 Conceptual Questions 12, 13, 15, 17[1] and Problems 32, 33[2], 35, 37, 55, 56, 57 (a only), 58, 82[3], 84 (conceptual only) and 87 (conceptual only)

LABORATORY COMPONENT: Work-Energy Theorem

[1] 17 and 33 relate very closely. Use each to help you with the other.

[2] Use 17 for help, and ALSO find the ratio of K to compare each case (horizontal, vertically straight up, and vertically straight down.)

[3] For 82 only the conceptual questions and part (c) of the problems.