Physics Education Laboratory
Lecture 08 - p3
PCK for Dynamics / Energy

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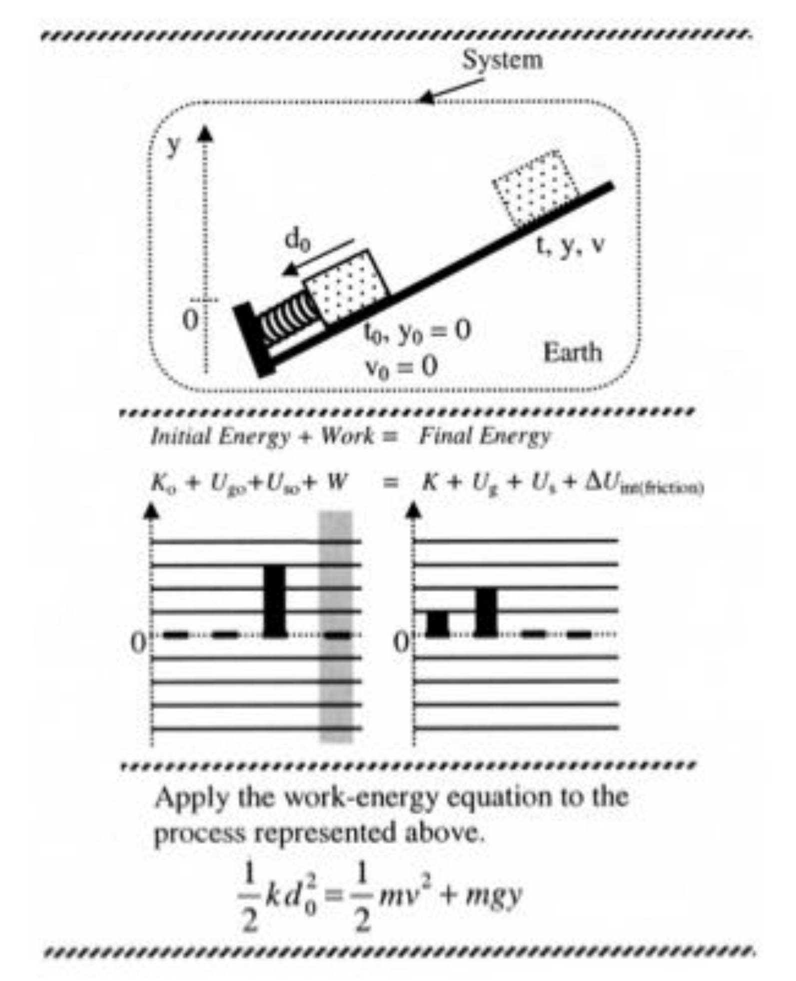
Conceptual ideas and skills about work-energy process that students have to know/possess

- Choosing a system—the object or objects of interest for the process being considered;
- Characterizing the initial state and the final state of the process;
- Identifying the types of energy that change as the system moves from its initial state to its final state and the signs of the initial and final energies of each type;
- Deciding if work is done on the system by one or more objects outside the system as the system changes states;
- Developing the idea that the initial energy of the system plus the work done on the system leads to the final energy of the system—the energy of the universe remains constant;
- Constructing an energy bar chart—a qualitative representation of the work – energy process;
- Converting the bar chart to a mathematical representation that leads to a problem solution.

The work–energy problem is originally described in the detailed sketch. Students are asked to convert the sketch into a qualitative bar chart —a bar is placed in the chart for each type of energy that is not zero, and the sum of the bars on the left is the same as that of the bars on the right.

Then the generalized mathematical work–energy equation without any numbers is set up with one energy expression for each bar on the chart.

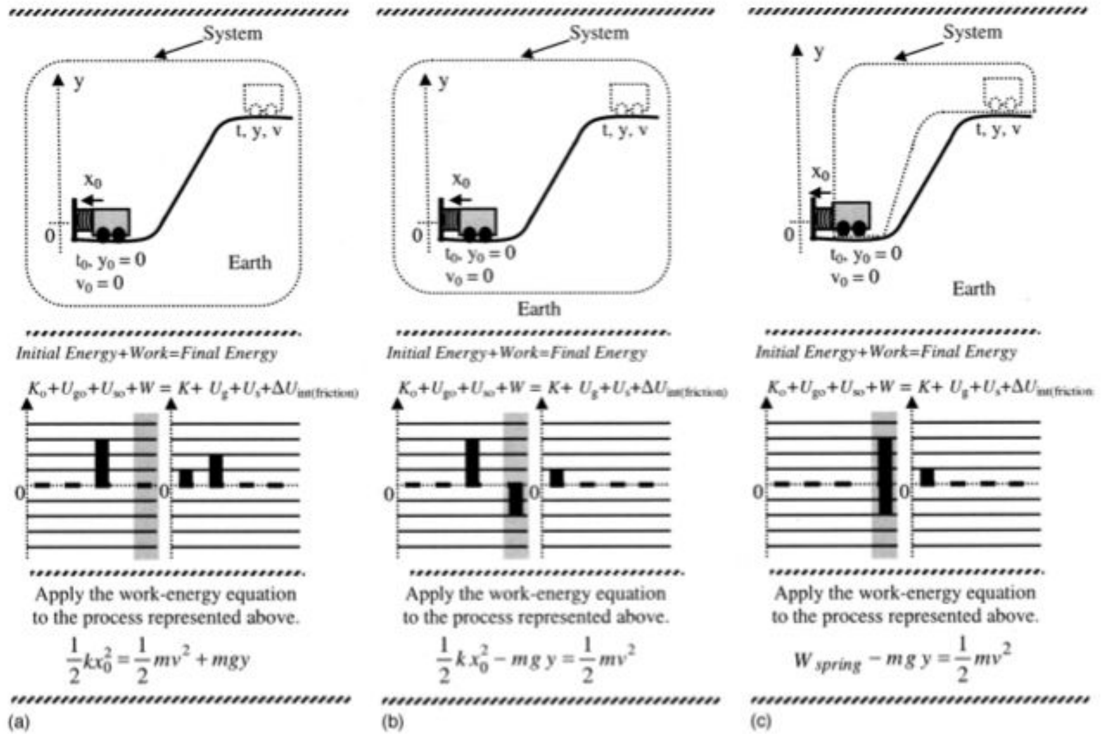
Notice that the work part in the bar chart is shaded so as to distinguish conceptually between work and energy, that is, work is a process quantity, but energy is a state quantity.



The different systems are chosen for the same physical process.

(a) The cart, the spring, and Earth are in the system.
(b) The cart and the spring are in the system, but not Earth.
(c) The system includes only the cart.
For each chosen system there is one work–energy bar chart and the corresponding generalized work–energy equation.

In practice, it would be easy for students to use a system that includes Earth and the spring, although the choice of the system does not affect the physical results.

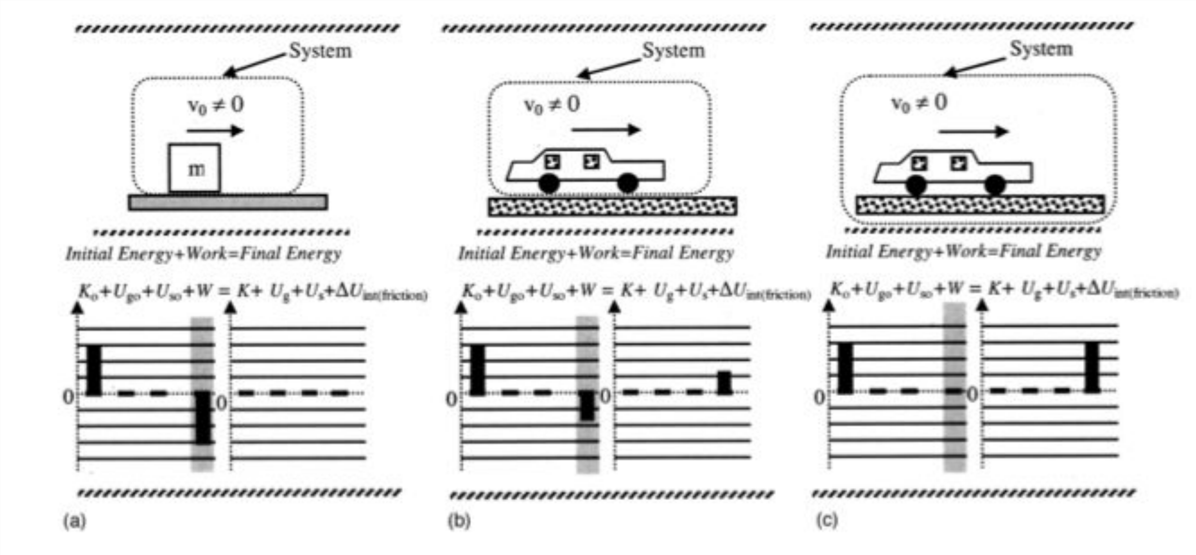


The physical processes involve friction.

(a) A point-particle block slides to a stop on a floor with friction. The system includes only the point-particle block. So the floor exerts an external frictional force on the point-particle block, and this frictional force does a negative amount of work, which has the same magnitude as the block's initial kinetic energy.

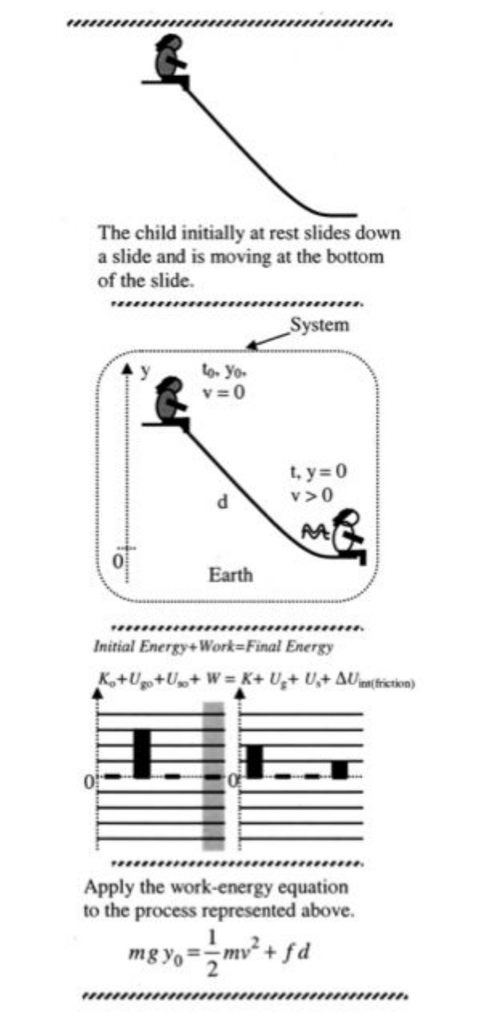
(b) A real car skids to a stop on a rough road. The car is the only object in the system. Thus the road that touches the car causes an external frictional force and a difficult work calculation

(c) And now? ..



https://www.physicsclassroom.com/Physics-Interactives/Work-and-Energy/Work-Energy-Bar-Charts/Work-Energy-Bar-Charts-Interactive

TEST YOURSELF!



For the given work–energy process, students are asked to construct the detailed sketch, and then convert it to an energy bar chart.

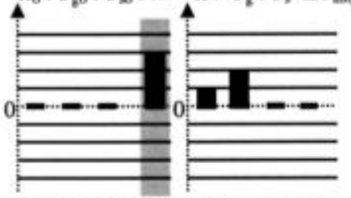
Finally, they use the bar chart to apply the generalized work–energy equation.

Verbal Representation

Pictorial Representation

Initial Energy+Work=Final Energy

$K_o + U_{go} + U_{so} + W = K + U_g + U_s + \Delta U_{int(friction)}$



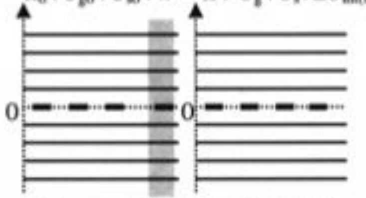
Mathematical Representation

Verbal Representation

Pictorial Representation

Initial Energy+Work=Final Energy

$K_o + U_{go} + U_{so} + W = K + U_g + U_s + \Delta U_{int(friction)}$

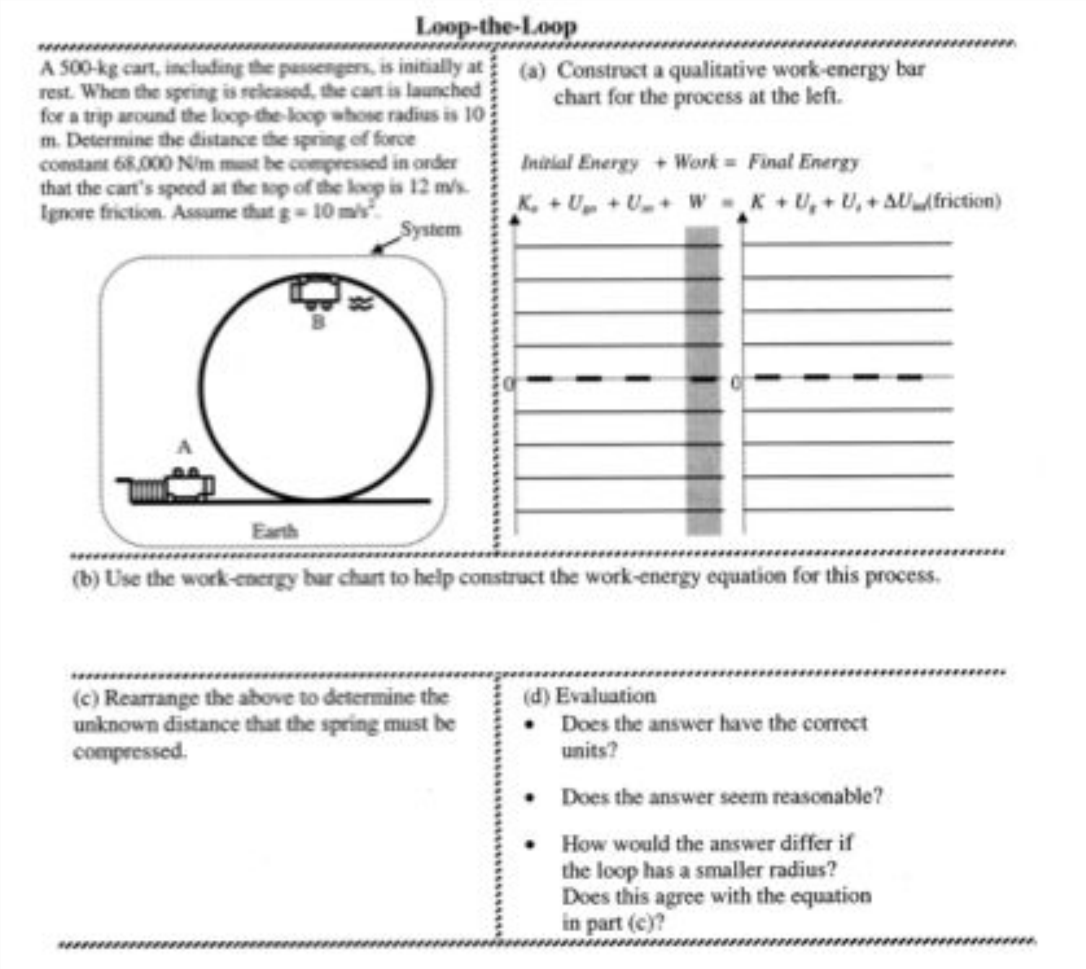


Mathematical Representation

$$(10\,\text{kg})(10\,\text{m/s}^2)(20\,\text{m}\sin 35^0)$$
$$= 0.5\,k\,(20\,\text{m})^2 + (30\,\text{N})(20\,\text{m})$$

One of the quantitative problems included in the Active Learning Problem Sheets. Students solve these problems using the multiple-representation strategy after having developed skills to construct qualitative representations.

These multiple-representation problems help students develop qualitative understanding about the physical processes and develop problem- solving expertise, instead of using only an equation- centered method.



Loop-the-Loop

A 500-kg cart, including the passengers, is initially at rest. When the spring is released, the cart is launched for a trip around the loop-the-loop whose radius is 10 m. Determine the distance the spring of force constant 68,000 N/m must be compressed in order that the cart's speed at the top of the loop is 12 m/s. Ignore friction. Assume that $g = 10\ m/s^2$.

(a) Construct a qualitative work-energy bar chart for the process at the left.

Initial Energy + *Work* = *Final Energy*

$K_a + U_{ga} + U_{sa} + W = K + U_g + U_s + \Delta U_{int}$(friction)

(b) Use the work-energy bar chart to help construct the work-energy equation for this process.

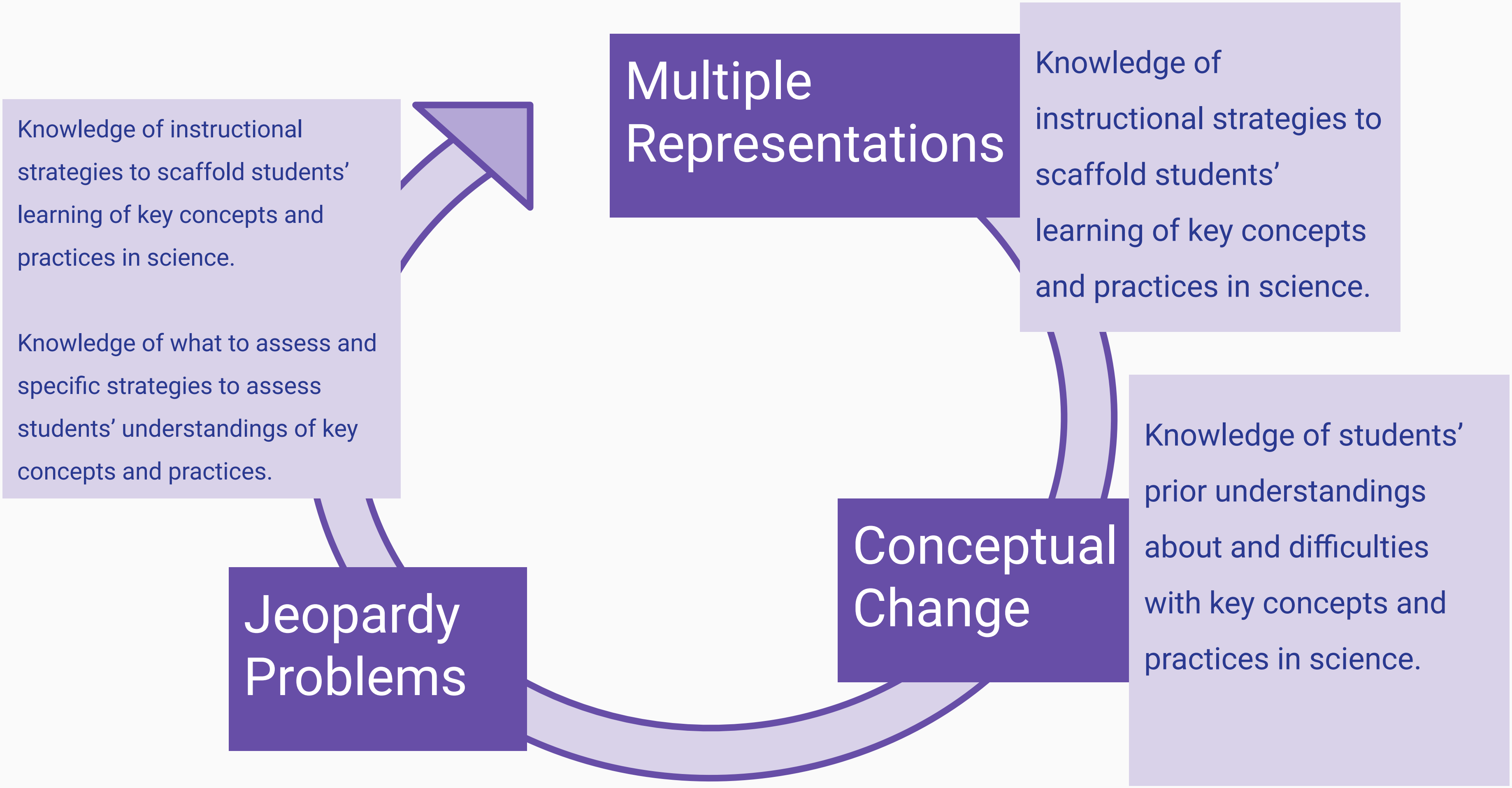
(c) Rearrange the above to determine the unknown distance that the spring must be compressed.

(d) Evaluation

- Does the answer have the correct units?
- Does the answer seem reasonable?
- How would the answer differ if the loop has a smaller radius? Does this agree with the equation in part (c)?

Genuine understanding is most likely to emerge...if people possess a number of ways of representing knowledge of a concept or skill and can move readily back and forth among these forms of knowing.

(Gardner, 1991)



HOW TO DEVELOP DIFFERENT PCK'S ASPECTS and CONTENT KNOWLEDGE FOR TEACHING

Jeopardy problems

Physics Jeopardy problems require students to work backwards. Instead of constructing and solving equations pertaining to a given physical situation, students are asked to construct a proper physical situation from a given equation or graph.

(Cui et al., 2006)

EXAMPLES:

Jeopardy problems ensure that “students cannot use formula-centered, plug-and-chug problem solving methods, rather they must give meaning to symbols in the equation” and “help students to learn to translate between representations in a more robust manner.”

(Van Heuvelen et al., 1999)

Jeopardy Equations:

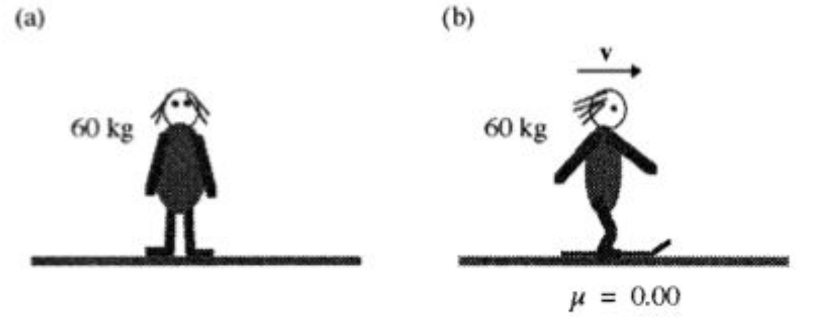


Fig. 1. The equation $N-(60\text{ kg})(9.8\text{ m/s}^2)=0$ describes the situations shown in (a) and (b).

In Equation Jeopardy, you reverse the normal process by providing a mathematical equation as the given information and asking the student to construct an appropriate physical situation that is consistent with the equation.

Consider a Jeopardy Problem involving the component form of Newton's second law applied to an object on an incline,

$$150\ \text{N} - (14.5\ \text{kg})(9.8\ \text{m/s}^2)\sin 34° - (0.32)(14.5\ \text{kg}) \times (9.8\ \text{m/s}^2)\cos 34° = (14.5\ \text{kg})a_x .$$

With a little work, a physicist will recognize that something exerts a 150-N force parallel to a 34° incline while pulling (or pushing) a 14.5-kg object up the incline. There is friction with a 0.32 kinetic friction coefficient between the object and the inclined surface. This Jeopardy Problem is somewhat more challenging.

We can ask the students to translate from the mathematical representation to a physics sketch, a free-body diagram in this case, and then from the diagram to a picture-like sketch of an appropriate physical situation.

Finally, students could be asked to invent a word problem that is consistent with the equation.

In Diagrammatic and Graphical Jeopardy Problems, students are first given a diagram or graph.

They then invent a word or picture description and a math description for a process that is consistent with the diagram or graph. Consider the force diagram in Fig. 2(a). Tell as much about the situation as you can.

The force diagram could describe a box or block moving downward at constant velocity along a vertical wall (Fig. 2(b)).

The normal force indicates that the object is pressed against a vertical wall. The kinetic friction force indicates that the object is moving down.

Notice that the y components of the forces parallel to the wall's surface add to zero.

This provides a nice opportunity to confront the common belief "misconception" that there must be a net force in the direction of motion in order for that motion to continue.

Diagram and Graph Jeopardy problems:

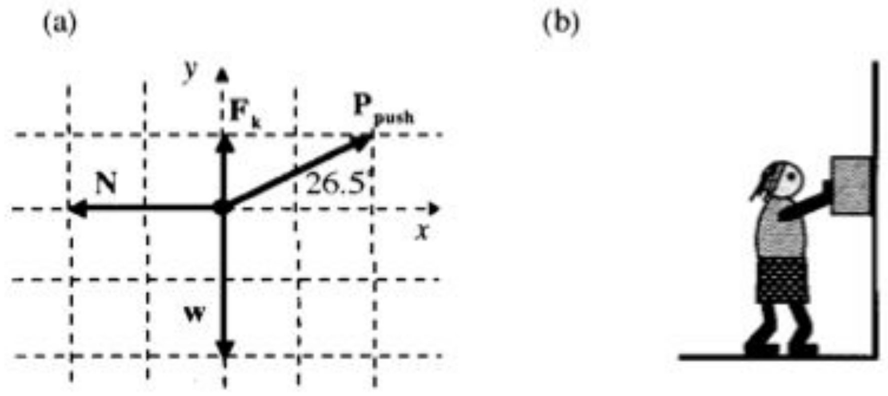


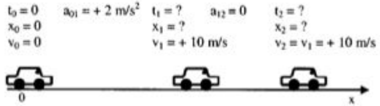
Fig. 2. The free-body diagram shown in (a) represents the process shown in (b).

Multiple Representations in Kinematics

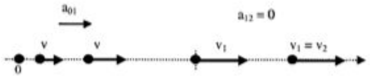
Verbal Representation

A car at a stop sign initially at rest starts to move forward with an acceleration of 2 m/s^2. After the car reaches a speed of 10 m/s, it continues to move with constant velocity.

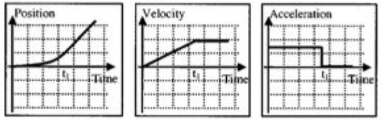
Pictorial Representation



Physical Representation (Motion Diagram)



Physical Representation (Kinematic Graphs)



Mathematical Representation

For $0 < x < x_1$ and $0 < t < t_1$	For $x_1 < x$ and $t_1 < t$
$x = 0 + 0 \bullet t + (1/2)(2 \text{ m/s}^2)\, t^2$	$x = x_1 + (10 \text{ m/s})\, t$
$v = 0 + (2 \text{ m/s}^2)\, t$	$v = +10$ m/s

Fig. 1. The kinematics process described in the problem can be represented by qualitative sketches and diagrams that contribute to understanding. The sketches and diagrams can then be used to help construct with understanding the mathematical representation.

A crate moves along a vertical wall. The application of Newton's second law in component form to that crate is shown below (the y-axis points up). Assume that g = 10 m/s^2.

$$F \cos 60^0 + \quad 0 \quad - N + \quad 0 \quad = 0$$

$$F \sin 60^0 + 0.40\, N + 0 - 200 \text{ N} = (20 \text{ kg})(-0.50 \text{ m/s}^2)$$

What is the object's mass? 20 kg

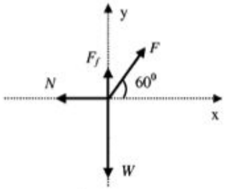
What is the object's weight? 200 N

How many forces act on the object? 4

Solve the equations for the unknowns.

$F = 178$ N, $N = 89$ N

Draw below a set of coordinate axes, one horizontal and the other vertically up. Then, examine the components of each force one at a time and draw arrows representing each force, thus constructing a free-body diagram.



Describe in words and/or in a drawing some real situation that might result in the diagram above.

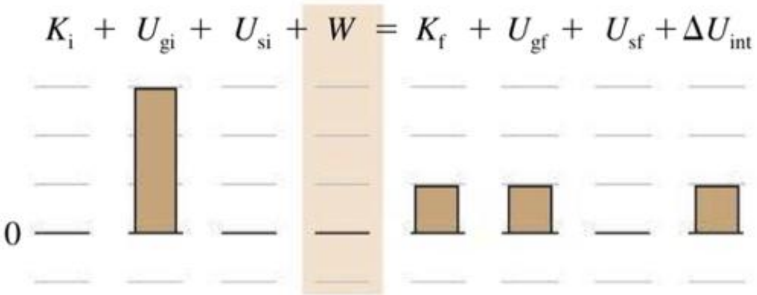
Fig. 2. The physical process described in the mathematical equations can be represented by diagrams, sketches, and words. The diagrams and sketches aid in understanding the symbolic notations, and help give meaning to the abstract mathematical symbols. (There could be more than one diagram and sketch consistent with the mathematical equations.)

Multiple Representations in Kinematics and Dynamics mean a wide usage and application of Jeopardy problems

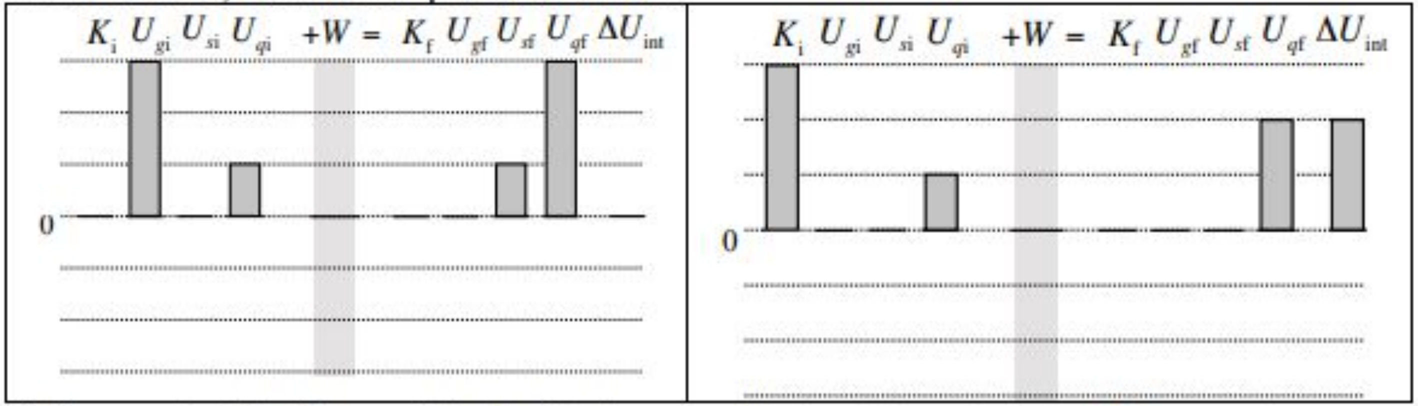
11. • **Jeopardy!** Contestants on the game show *Jeopardy!* depress spring-loaded buttons to "buzz in" and provide the question corresponding to the revealed answer. The force constant on these buttons is about 130 N/m. Estimate the amount of energy it takes—at a minimum—to buzz in.

39. * **Bar chart Jeopardy 1** Invent in words and with a sketch a process that is consistent with the qualitative work-energy bar chart shown in **Figure P6.39**. Then apply in symbols the generalized work-energy principle for that process.

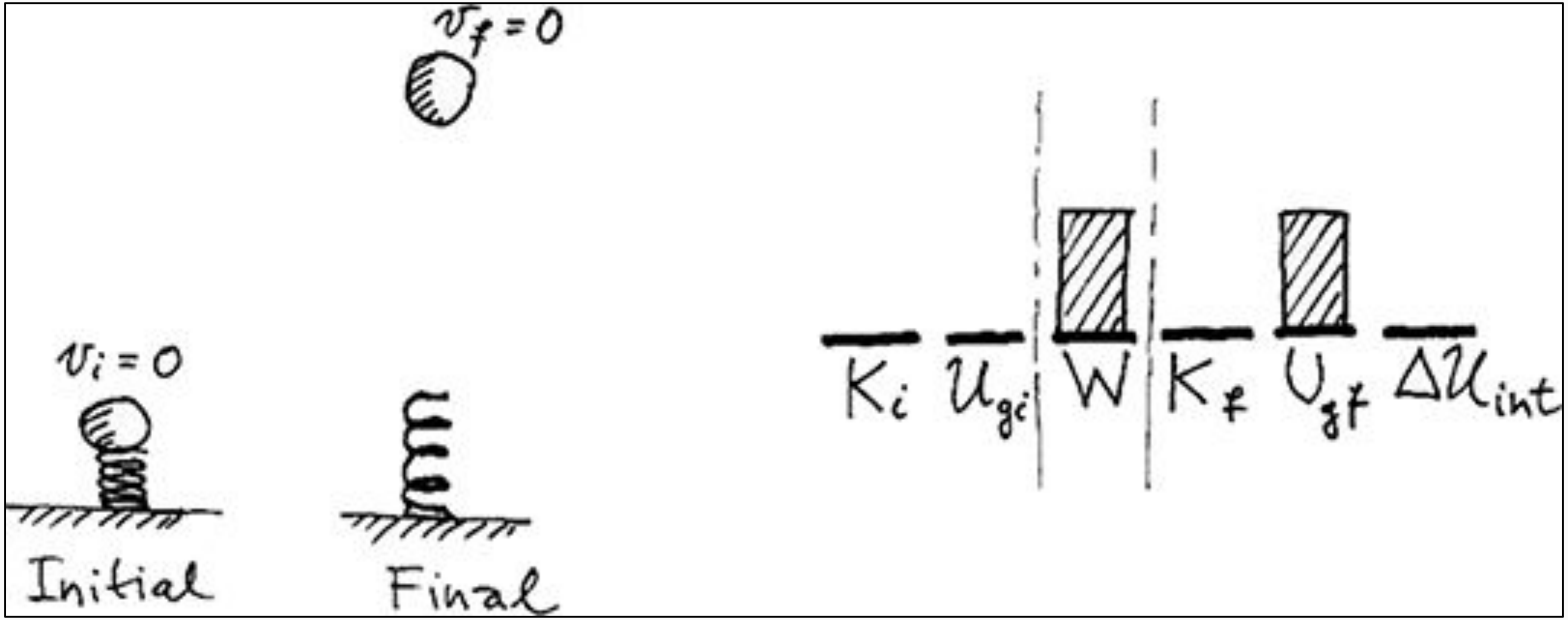
Figure P6.39



4. Bar chart jeopardy: The two bar charts below could represent many processes. Separately, for each bar chart, answer the questions below.



a) Draw a sketch of a possible physical process that each bar chart could represent.
b) Describe the physical process in words.
c) Construct a work-energy equation that each bar chart could represent.



$v_f = 0$
$v_i = 0$
Initial
Final
K_i
U_{gi}
W
K_f
U_{gf}
ΔU_{int}