Name: ______________________

Class: ______________________

Due Date: ______________________

A.3 Work, Energy, and Power

Understandings

- The principle of the conservation of energy.
- Work done by a force is equivalent to a transfer of energy.
- Energy transfers can be represented on a Sankey diagram.
- Work W done on a body by a constant force depends on the component of the force along the line of displacement as given by $W = Fs\ \cos\theta$.
- Work done by the resultant force on a system is equal to the change in the energy of the system.
- Mechanical energy is the sum of kinetic energy, gravitational potential energy, and elastic potential energy.
- In the absence of frictional, resistive forces, the total mechanical energy of a system is conserved.
- If mechanical energy is conserved, work is the amount of energy transformed between different forms of mechanical energy in a system such as
  - the kinetic energy of translational motion as given by $E_{\mathrm{k}} = \frac{1}{2}mv^2 = \frac{p^2}{2m}$
  - the gravitational potential energy, when close to the surface of the Earth as given by $\Delta E_{\mathrm{p}} = mg\Delta h$
  - the elastic potential energy as given by $E_{\mathrm{H}} = \frac{1}{2}k\Delta x^2$
- Power developed P is the rate of work done, or the rate of energy transfer, as given by $P = \frac{\Delta W}{\Delta t} = Fv$
- Efficiency η in terms of energy transfer or power as given by $\eta = \frac{E_{\text{output}}}{E_{\text{input}}} = \frac{P_{\text{output}}}{P_{\text{input}}}$
- Energy density of the fuel sources.

Equations

$W = Fs\ \cos\theta$

$E_k = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

$\Delta E_p = mg\Delta h$

$E_H = \frac{1}{2}k\Delta x^2$

$P = \frac{\Delta W}{\Delta t} = Fv$

$\eta = \frac{E_{output}}{E_{input}} = \frac{P_{output}}{P_{input}}$

Equation not given in IB Physics Data Booklet:

$W = \Delta E_k = E_{k,f} - E_{k,i}$

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Answer the following questions

1. What is the meaning of *work*? Equation? Units? Is it a scalar or vector?

2. What is the meaning of *energy*? Units? Is it a scalar or vector?

3. What is the meaning of *kinetic energy*? Equation? Define each variable.

4. What will happen to the kinetic energy of a moving object if its
   a. Mass halves and speed halves?

   b. Mass doubles and speed doubles?

   c. Mass decreases by three (one third) and speed increases by four (quadruples)?

5. What is the meaning of *potential energy*?

6. What is the meaning of *gravitational potential energy*? What is the equation for *gravitational potential energy* of an object near the surface of a planet? Define each variable. What is the general equation for the *gravitational potential energy* between two objects? Define each variable.

7. What is the equation for the *elastic potential energy* of a compressed or stretched spring? Define each variable. What is the meaning and units for the *spring constant k*?

8. What is the equation for the *total mechanical energy* of an object?

9. True or false: Work is done on an object if the object moves.

10. What is the work done on a 3 kg rock if it travels 60 m with a constant speed of 4 m/s in outer space?

11. What does the slope of a *force vs. displacement* graph tell us?

12. What does the area under a *force vs. displacement* graph tell us?

13. What is the meaning of *power P*? Equation? Units? Is it a scalar or vector? Do not confuse power P with pressure P or momentum $\vec{p}$ or density ρ!

14. What is the meaning of and the equation for the *law of conservation of energy*?

15. State the equation for the work-energy theorem.

16. What are some characteristics of a *Sankey diagram*? Sketch a simple *Sankey diagram*.
http://sankeymatic.com/

17. What is *efficiency*? Equation? Units? Is it a scalar or vector?

Part 2: Answer the following questions

1. Job pulls a massless rope at an angle of 40° from the horizontal which is attached to a block of mass $m = 60\ kg$ on a rough horizontal surface with a coefficient of friction of $\mu = 0.2$ with a constant speed of 2 m/s for 300 m.

   a. Draw a free body diagram.

   b. Use Newton's second law of motion to find F_{pull}.

   c. How much work was done by Job?

   d. What is the average power performed by Job?

2. A 10 kg object initially at rest is 12 m above the surface of the Earth. It is released. There is no air friction.

   a. Draw a figure.

   b. What is the initial kinetic energy of the object?

   c. What is the initial gravitational potential energy of the object?

   d. What is the initial total energy of the object?

   e. What is the kinetic energy of the object when it is halfway to the surface?

   f. What is the gravitational potential energy of the object when it is halfway to the surface?

   g. What is the total energy of the object when it is halfway to the surface?

   h. What is the final gravitational potential energy of the object just before it reaches the surface?

i. What is the final kinetic energy of the object just before it reaches the surface?

j. What is the total energy of the object just before it reaches the surface?

k. What is the final speed of the object just before it reaches the ground? From part d the total energy of the object is $1{,}177.2\ J$.

l. Draw a *gravitational potential energy vs. height* graph, a *kinetic energy vs. height* graph, and a *total energy vs. height* graph.

3. Jethro throws a 5 kg object from the surface of the Earth vertically upwards with an initial speed of 8 m/s. There is no air friction.

   a. Draw a figure.

   b. What is the initial gravitational potential energy of the object?

   c. What is the initial kinetic energy of the object?

   d. What is the initial total energy of the object?

   e. What is the maximum height the object will travel?

   f. How long will it take for the object to reach its maximum height?

   g. What is the gravitational potential energy of the object when it is halfway to its maximum height?

   h. What is the kinetic energy of the object when it is halfway to its maximum height?

   i. What is the total energy of the object when it is halfway to its maximum height?

j. What is the gravitational potential energy of the object when it reaches its maximum height?

k. What is the kinetic energy of the object when it reaches its maximum height?

l. What is the total energy of the object when it reaches its maximum height?

m. What is the speed of the object when it reaches its maximum height?

n. Draw a *gravitational potential energy vs. height* graph, a *kinetic energy vs. height* graph, and a *total energy vs. height* graph.

4. A 8 kg object is falling vertically freely with a speed of 40 m/s at an elevation of h_1. What will be the speed of the object after it has fallen a distance of 70 m? Round your answer to two decimal places.

5. A 8 kg object is falling down with a speed of 40 m/s at an elevation of 300 m. After the object has fallen a distance of 90 m its speed is now 45 m/s.

    a. What is the magnitude of energy lost from air friction? Round your answer to two decimal places.

    b. What is the magnitude of the force of air friction during this 90 m? Round your answer to two decimal places.

6. A 7 kg object is placed on a 12 m long smooth incline which is 30° above the horizontal. It is released and slides down.

   a. Draw a figure.

   b. What is the initial height of the object?

   c. What is the initial gravitational potential energy of the object?

   d. What is the initial kinetic energy of the object?

   e. What is the initial total energy of the object?

   f. What is the final speed of the object when it reaches the bottom of the incline?

   g. What is the final kinetic energy of the object?

   h. What is the final gravitational potential energy of the object?

   i. What is the acceleration of the object?

   j. How long does it take for the object to reach the bottom of the incline?

7. A 4 kg block is placed on a 20 m long rough incline which is 30° above the horizontal. The coefficient of friction between the block and the incline is $\mu = 0.3$. The block is released and slides down.

a. Draw a figure.

b. What is the initial height of the object?

c. What is the initial gravitational potential energy of the object?

d. What is the initial kinetic energy of the object?

e. What is the initial total energy of the object?

f. What is the normal force acting on the block?

g. What is the force of friction acting on the block?

h. What is the final speed of the object when it reaches the bottom of the incline?

i. What is the acceleration of the object?

j. What is the final kinetic energy of the object?

k. What is the final gravitational potential energy of the object?

l. What is the final total energy of the object?

m. How long will it take for the object to reach the bottom of the incline?

n. How much energy was lost by the block?

8. A 6 kg block is moving to the right with a constant speed of 22 m/s on a horizontal frictionless surface. The block then goes up a 30° incline which has a coefficient of friction of 0.8.

a. Draw a figure.

b. How many meters up the incline and how high does the block move?

9. A horizontal spring with a spring constant $k = 3{,}000\,\frac{\mathrm{N}}{\mathrm{m}}$ is compressed 6 cm by an 800 gram block which is resting on a frictionless surface. The block is then released from rest.

a. Draw a figure.

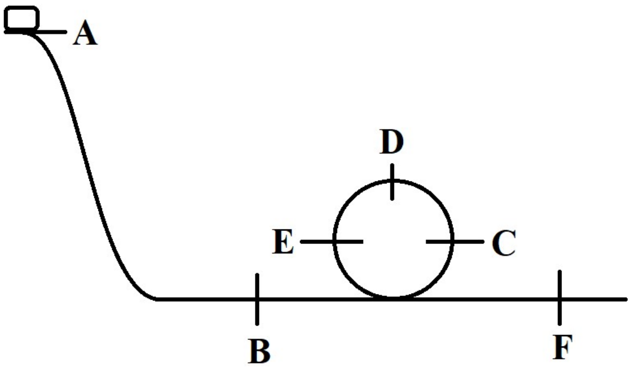
b. What is the initial potential energy of the spring?

c. What is the kinetic energy of the block after it leaves the spring?

d. What is the final speed of the block after it leaves the spring?

e. After some distance the block moves through a rough surface with a coefficient of friction $\mu = 0.05$. What is the total distance the block travels along the rough surface?

10. A 425 kg roller coaster begins from rest at a height $h_1 = 140$ m above the surface of the Earth. The roller coaster makes a circular loop with a radius of $r = 24$ m.



a. Determine the total energy of the roller coaster at points A, B, C, D, E, and F. Write neatly, show all your work, and place a box around all six of your answers.

b. Determine the gravitational potential energy of the roller coaster at points A, B, C, D, E, and F. Write neatly, show all your work, and place a box around all six of your answers.

c. Determine the kinetic energy of the roller coaster at points A, B, C, D, E, and F. Write neatly, show all your work, and place a box around all six of your answers.

d. Determine the speed of the roller coaster at points A, B, C, D, E, and F. Write neatly, show all your work, and place a box around all six of your answers.