SPH4U-C

Unit 2

Energy and Momentum

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Introduction

You may hear words like "momentum," "energy," and "work" spoken in everyday conversations or on the evening news during the sportscast. In physics, these words have more specific meanings and are used to analyze a wide variety of things. For example, electric power, car crashes, and roller-coaster rides are all described in terms of work, power, and momentum.

Engineers use their understanding of energy and momentum to design cars and highways that reduce traffic accidents and automobile injuries. Some of the laws that our government passes are based on these ideas as well, but there is still plenty of debate as to whether these laws are effective. By the end of this unit, you should be able to form your own opinion.

Overall Expectations

After completing this unit, you will be able to

- distinguish between gravitational potential energy, kinetic energy, and thermal energy, and solve energy-related problems
- apply the work-energy theorem and the law of conservation of energy
- solve problems related to elastic potential energy and simple harmonic motion
- solve problems using impulse and momentum
- analyze collisions in two dimensions using conservation of momentum

SPH4U-C

Lesson 5

Work and Energy

Introduction

Can you remember the last time you experienced a power outage? Were you bothered by the lack of a TV, a computer, an oven, or perhaps running water? You may have then realized how much we depend on electricity. It has become a necessity rather than a convenience.

The electricity coming from hydroelectric, nuclear, and wind turbine facilities (among others) is available to us due to energy transformations. For example, in hydroelectric generating stations, water falls onto a turbine, causing it to spin. A changing magnetic field around a coil creates the flow of current. Although other transformations happen along the way, this current is what allows the light in our light bulbs to shine; the energy in the moving water eventually becomes the energy in the light from a bulb. The development of electric generators is one of the most transformative developments in our history, making our world an entirely different place.

Every development, though, has its challenges. The construction of power-generating stations has been known to destroy some birds' migration patterns, as well as the habitats of some animals. There is also existing research that suggests that generators can cause health problems for those people living near them. Wind turbines—one of the cleanest renewable resources we have—tend to be so noisy that people who live nearby experience high stress and have difficulty sleeping. Nuclear energy—another cleaner alternative—results in waste products that are dangerously radioactive. Solar energy, however, seems to be an excellent electricity-producing alternative. For the average homeowner, though, the materials and installation necessary for solar energy are very expensive and thus require some financial planning.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Work	1
Energy	½
Work-Energy Theorem	½
Thermal Energy	½
Conservation of Energy	1
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- apply work and energy concepts qualitatively and quantitatively
- distinguish between gravitational potential energy, kinetic energy, and thermal energy, and solve energy-related problems
- apply the work-energy theorem and the law of conservation of energy

Work

You are going to start this lesson by doing some "physics" work.

- Take a rubber ball. Raise the ball to some height, and then release it. What happens?

  The ball falls, of course.

- As the ball falls, try to observe what happens to its speed. Does it seem to be constant, increasing, or decreasing?

  You should notice that the ball's speed increases as it falls. Just think back to the last unit and recall that as an object experiences free fall, it accelerates at a rate of 9.8 m/s^2 toward the earth. Your ball's speed increases as it falls.

- After your dropped ball bounces, does it travel back up to the height from which it was dropped?

  As you see, it doesn't. Depending on the nature of the material, the height to which it returns will vary. Why? You'll learn about that in this lesson.

- Play around with the ball to figure out what you would have to do to ensure that the ball bounces back to its original height.

  In order for that to happen, you would have to exert some force when you throw the ball downward. Or, you could toss the ball upward instead. This would also allow the ball to bounce back to its release point. Either way, you'd have to do more work!

What Is Work?

When lifting a ball, as in the previous activity, or when exerting force to throw a ball, you are doing work by exerting a force that results in displacement. In physics, work is defined as the transfer of energy by means of exerting a force that causes displacement. Quantitatively, the amount of work done is equal to the dot product of force and displacement. A dot product is a way of multiplying vector quantities that only counts those parts of the vectors that are parallel to each other. For any work to be done, the force and the displacement must be parallel.

In equation form:

$W = \vec{F} \bullet \Delta \vec{d}$, where W = work done measured in joules (J), $\vec{F}$ = force exerted measured in newtons (N), and $\Delta \vec{d}$ = the resulting displacement measured in metres (m). This equation expands to a form used in calculations. It becomes $W = F\Delta d \cos\theta$, where the angle stated is formed between the force vector and the displacement vector. This means that only the component of the force in the displacement direction creates work!

Note that work is a scalar quantity. Being the dot product of two vectors, it has magnitude and a unit, but no direction. The unit for measuring work is the joule. In terms of base units, 1 J = 1 Nm = 1 kgm^2/s^2.

Example 1

A ball is lifted 1.0 m by an upward force of 2.0 N. Calculate the work done on the ball by this force.

Solution

Given:

$\Delta\vec{d} = 1$ m [up]

$\vec{F} = 2$ N [up]

Required: W

Analysis and solution:

Let up be positive.

$W = \vec{F} \bullet \Delta\vec{d}$

$W = F\Delta d\cos\theta$ where $\theta = 0°$ and $\cos 0° = 1$

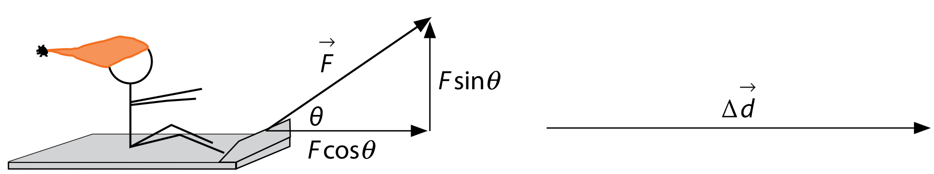
This is because both vectors are fully aligned in the same direction.

$w = (2\text{ N})(1\text{ m})$

$w = 2\text{ J}$

Paraphrase: Therefore, 2 J of work is done on the ball.

In the above example, the force on the ball was exerted in the exact same direction as the resultant displacement of the ball. Sometimes, however, the force exerted on an object being displaced is not exerted entirely in the same direction as its displacement. For example, if you were pulling a child on a sled along a flat surface, the rope you would be pulling would likely be at an angle. Only the amount of force exerted in the forward direction ($F\cos\theta$) would contribute to the forward displacement.



In determining the amount of work done in such situations, you must consider only the component of force in the forward direction. Therefore, you would use the equation:

$W = F\Delta d\cos\theta$

where W = work done in joules (J)

F = magnitude of force exerted in newtons (N)

θ = angle between the direction of displacement and the direction of the force

Δd = magnitude of displacement (m)

Note that the vector symbols are omitted in this equation because, once you have included the angle, you are only considering magnitudes, not directions, in the calculation.

Example 2

A crate is pulled 4.00 m along a level surface by a horizontal force of 100.0 N. Determine the amount of work done by the force.

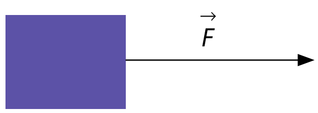
Solution

Given:

$\Delta d = 4.00$ m

$F = 100.0$ N

$\theta = 0°$ (because both force and displacement are acting in the same direction)



Required: W

Analysis and solution:

$W = F\Delta d\cos\theta$

$W = (100.0\text{ N})(4.00\text{ m})\cos 0$

$W = 400$ J

Paraphrase: Therefore, the work done by the force on the crate is 400 J.

Example 3

The same crate as that in the previous example is now pulled 4.00 m along a level surface by a force of 100.0 N exerted on a rope that makes an angle of 25° with the direction of the horizontal displacement. Determine the amount of work done by the force.

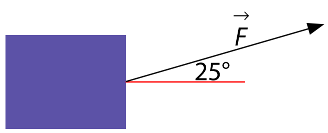
Solution

Given:

$\Delta d = 4.00$ m

$F = 100.0$ N

$\theta = 25°$



Required: W

Analysis and solution:

$W = F\Delta d\cos\theta$

$W = (100.0 \text{ N})(4.00 \text{ m})\cos 25°$

$W = 362$ J

Paraphrase: Therefore, the work done by the force on the crate is 362 J.

Negative Work

Sometimes, an object that is being displaced experiences a force in a direction opposite to its direction of motion. The most common example of this is the force of kinetic friction. Forces that are opposed to motion do not, of course, contribute to the forward displacement, but they do have the effect of hindering the motion and therefore do what is called "negative" work.

Example

The same crate that was being pulled 4.00 m along a level surface by a horizontal force of 100.0 N also experiences a force of friction of 10 N. Determine the

a) amount of work done by the force of friction.

b) total work done on the crate.

Solution

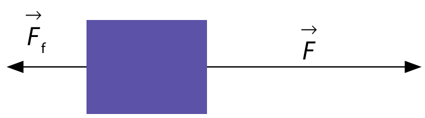
a) Given:

$\Delta d = 4.00$ m

$F_f = 10$ N

$\theta = 180°$

This is the angle from the force vector going counterclockwise back to the friction vector.



Required: Work done by friction

Analysis and solution:

$W = F\Delta d\cos\theta$

$W = (10\text{ N})(4.00\text{ m})\cos180°$

$W = 40\text{ J}(-1)$

Paraphrase: Therefore, the work done on the crate by the force of friction is –40 J.

b) Required: W_{total}

Analysis and solution: From a previous example (or from a quick calculation), you know that the work done on the crate by the pull (pulling force) was 400 J. Therefore:

$W_{total} = W_{pull} + W_{friction}$

$W_{total} = 400.0\text{ J} + (-40.0\text{ J})$

$W_{total} = 360\text{ J}$

Paraphrase: Therefore, the total work done on the crate is 360 J. This is also referred to as the net work done in a system.

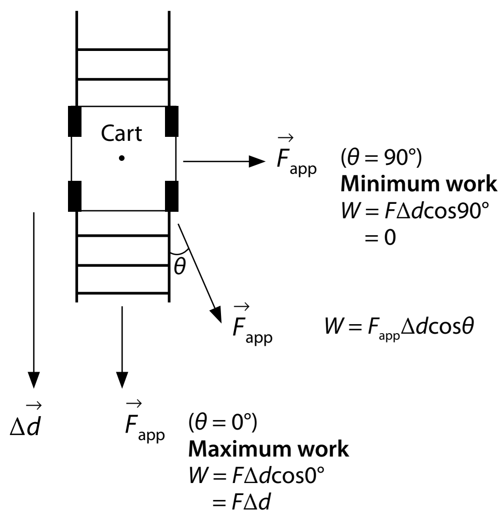
Zero Work

Sometimes, forces exerted on objects do not contribute to displacement at all. Can you think of an example of this? Here is a hint: At what angle will the cosine function give a result of 0? If you figured out 90°, then you got it right!

Whenever a force is exerted perpendicular to the direction of displacement, it does not contribute to forward motion. Try it: place a book on a table. If you push the book horizontally, you get displacement. If you push the book at an angle, you get displacement. If you push straight down on the book, it doesn't move. Zero displacement means that zero work is done.

Consider a more complicated situation. You are trying to pull a small railway cart on a linear track. If you pull the cart in the direction of the tracks ($\theta = 0°$), you will do maximum work. If you pull at an angle to the tracks, the cart still moves and you do work, except that the amount of work will not be as great as in the previous example because you are not as efficient. ($W = F\Delta d\cos\theta$ and the cosine part of the equation reduces the value of W.)

Top view of cart on railway tracks



Now, if you were to pull sideways to the track, and assuming you do not pull the cart off the track, you will do no work even though you pulled with all your might.

In this case, $\theta = 90°$ and $\cos 90° = 0$, so the work equation becomes equal to zero.

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided. Click on each "Suggested answer" button to check your work.

1. A boy pushes a lawnmower 60.0 m by exerting a force of 20.00 N onto the handle at an angle of 30° below the horizontal axis. The lawnmower also experiences a force of friction of 5.00 N. Calculate the amount of work done on the lawnmower
   a) by the boy.
   b) by the friction.
   c) in total.

Suggested answer

2. Determine whether positive work, negative work, or zero work is being done by the objects in italics, in the following situations.
   a) A *landscaper* exerts all her force forward on a boulder that does not move.
   b) A feather is blown forward by the *wind*.
   c) A baby is carried across the room in his mother's *arms*. Find the vertical work done.
   d) Thanks to *friction*, a skater glides to a stop.

Suggested answer

Energy

As described in the previous section, work is the transfer of energy, but what exactly does it mean to give energy to an object?

Energy is the potential to do work. In transferring energy to an object, the object is given the ability to do something. For example, when you lifted the ball at the very beginning of this lesson, you were giving the ball the ability to fall.

There are many different forms of energy. In this lesson, you will focus on two types:

- Gravitational potential energy
- Kinetic energy

Gravitational Potential Energy

Gravitational potential energy is the energy that an object possesses due to its position, measured relative to some surface. It is equal to the work done against the force of gravity in moving the object to that height. Gravitational potential energy is the source of energy converted to create hydroelectricity. It is a scalar quantity that is dependent on mass, height, and gravitational field intensity. The equation for calculating gravitational potential energy (commonly referred to as GPE) is:

$\Delta E_g = mg\Delta h$, which is commonly written simply as $E_g = mgh$,

where m = mass measured in kilograms (kg), g = gravitational field intensity, which near earth's surface is 9.8 m/s^2, and h = height measured in metres (m).

The equation can be derived from the work formula $W = F\Delta d$. In this case, $F = mg$ and Δd is the height Δh. The angle between the force of gravity and the height is 0° so the cosine in the general formula for work becomes 1.

When calculating GPE, it is important to have a reference point. For example, if a book was lying on the surface of a desk, it would not have gravitational potential energy relative to the desk, but it would have gravitational potential energy relative to the floor. It is even possible for an object to have negative gravitational potential energy, if it is located at a lower height than the reference point.

By selecting a reference height h_1 and setting it to be zero, we are stating that $E_{g_1} = 0$ as well. This means we refer to the change from our zero reference point as E_{g_2} at h_2. We now remove the subscript 2 and imply that we are dealing with heights and energies from the reference point.

Example

A 45 kg skier gets onto a ski lift that brings her to a point 500.0 m above her starting point. What is the skier's gravitational potential energy relative to her starting point?

Solution

Given:

$m = 45$ kg

$h = 500.0$ m

Required: E_g

Analysis and solution:

$E_g = mgh$

$E_g = (45 \text{ kg})(9.8 \text{ m/s}^2)(500.0 \text{ m})$

$E_g = 220\,500 \text{ J} = 2.2 \times 10^5 \text{ J}$

Paraphrase: Therefore, the skier gains 2.2×10^5 J of gravitational potential energy.

Kinetic Energy

Kinetic energy refers to the energy that an object has, due to its motion. The amount of kinetic energy possessed by an object depends on its mass and speed, and is measured in joules. This scalar quantity is calculated using the following equation:

$E_k = \frac{1}{2}mv^2$, where E_k = kinetic energy measured in joules (J), m = mass measured in kilograms (kg), and v = speed measured in metres per second (m/s).

This equation is also derived from our definition of work.

Assume $\theta = 0°$ so $W = F\Delta d$

and we know that $F = ma$.

Recall that $\Delta d = \left[\frac{(v_1 + v_2)}{2}\right]\Delta t$

and $a = \frac{(v_2 - v_1)}{\Delta t}$.

Now substitute these into the work equation to obtain:

$$W = \left[m\frac{(v_2 - v_1)}{\Delta t}\right]\left[\frac{(v_2 + v_1)}{2}\right]\Delta t$$

We have slightly rearranged the vs to obtain the difference of squares equation:

$(v_2 - v_1)(v_2 + v_1)$, which equals $v_2^{\,2} - v_1^{\,2}$.

We now simplify and obtain:

$$W = \frac{mv_2^2}{2} - \frac{mv_1^2}{2}$$

However, if we assume that we start from rest, then $v_1 = 0$ and $E_{k_1} = 0$, leaving you with:

$W = E_k = \frac{1}{2}mv_2^{\,2}$

We then remove the subscript 2, and the implication is that the v is a speed achieved after work was done on the object.

Example

A 45.0 kg skier is skiing down a hill with a speed of 10.0 m/s. What is the skier's kinetic energy?

Solution

Given:

$m = 45.0$ kg

$v = 10.0$ m/s

Required: E_k

Analysis and solution:

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

$$E_k = \frac{1}{2}(45.0 \text{ kg})(10.0 \text{ m/s})^2$$

$$E_k = 2250 \text{ J}$$

Paraphrase: Therefore, the skier's kinetic energy is 2250 J.

Support Questions

3. Distinguish between work and energy. Suggested answer

4. Distinguish between gravitational potential energy and kinetic energy. Suggested answer

5. A 55.0 kg cyclist rides off the edge of a 5.0 m high cliff with a speed of 15 m/s. Determine the cyclist's gravitational potential energy relative to the ground below and his kinetic energy. Suggested answer

Work-Energy Theorem

Work is done when energy is transferred from one object to another or from one form to another. The energy transferred to an object enables it to do work. This idea is the foundation for what is known as the work-energy theorem.

The work-energy theorem states that the total work done on an object is equal to the object's change in kinetic energy, provided there is no change in any other type of energy, such as gravitational potential energy. This is expressed as follows:

$W = \Delta E_k$

Keep in mind that the work-energy theorem holds true as long as there are no other changes in energy. When other types of energy are involved, such as gravitational potential energy, elastic energy, and thermal energy, the work applied to the system is equal to the total change in energy. In such cases, the following more general expression is useful:

$W_{\text{applied to a system}} = \Delta E_{\text{system}}$

Example

A 45.0 kg cross-country skier accelerated himself from 0.0 m/s to 5.0 m/s. How much work did he do?

Solution

Given:

$m = 45.0$ kg

$v_i = 0.0$ m/s

$v_f = 5.0$ m/s

Required: W

Analysis and solution:

$W = \Delta E_k$

$W = E_{k2} - E_{k1}$

$W = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$

$W = \frac{1}{2}m(v_2^2 - v_1^2)$

$W = \frac{1}{2}(45.0 \text{ kg})(5.0 \text{ m/s}^2 - 0.0 \text{ m/s}^2)$

$W = 562.5 \text{ J} = 560 \text{ J}$

Paraphrase: Therefore, the skier did 560 J of work to accelerate to a speed of 5.0 m/s.

Support Questions

6. When a 1500 kg car is accelerated, starting from a rest position, 1.5×10^5 J of work is done. What speed does the car have, as a result?

Suggested answer

Thermal Energy

In an ideal situation, the work done on an object would all be turned into kinetic energy or some other useful form of energy. However, in real situations, some amount of friction is unavoidable, and results in the formation of another form of energy: thermal energy.

Thermal energy is the energy related to the motion of atoms in materials or, in other words, heat energy. Quantitatively, thermal energy is proportional to the force of kinetic friction and the displacement moved by the object, as shown in the following equation:

$E_{th} = F_f \Delta d$

Thermal energy is often referred to as waste energy, because it is energy that serves no purpose. When creating devices for motion, one of the main tasks of designers is to minimize friction and therefore the production of thermal energy. This is the case for motor vehicles and is even relevant for the development of sporting equipment. In the 2010 Olympic Winter Games, for example, speed skaters wore outfits that were the culmination of four years of research by the National Research Centre's Institute for Aerospace Research. These outfits, made of a combination of six materials, were more aerodynamic than human skin, minimizing the amount of friction and thermal energy experienced by the athlete. As a result, more of the athlete's work resulted in speed, making for stiffer competition.

Example

An 1800 kg SUV, needing to stop suddenly, skids to a stop over a distance of 5.0 m. If the coefficient of kinetic friction is 0.6, how much thermal energy is produced?

Solution

Given:

$m = 1800$ kg

$\mu = 0.6$

$\Delta d = 5.0$ m

Required: E_{th}

Analysis and solution:

$E_{th} = F_{kf}\Delta d$

$E_{th} = (\mu_k F_N)(\Delta d)$

$E_{th} = (\mu_k mg)(\Delta d)$

$E_{th} = (0.6)(1800\ \text{kg})(9.8\ \text{N/kg})(5.0\ \text{m})$

$E_{th} = 52\ 920\ \text{J} = 50\ 000\ \text{J}$

Paraphrase: Therefore, 50 000 J of thermal energy is produced.

Support Questions

7. As a 5.0 kg box slides 3.0 m along a level surface, 50.0 J of thermal energy is produced. What is the coefficient of kinetic friction between the box and the surface on which it slides?

Suggested answer

Conservation of Energy

Energy can be transformed or transferred from one object to another, but it can never really be lost. The law of conservation of energy states that energy can never be created or destroyed, but can be converted from one form into others. Therefore, in a system isolated from its surroundings, the total energy present remains constant, that is, $E_{initial} = E_{final}$.

Example 1

A 60.0 kg swimmer dives from a 7.0 m high cliff into the water. Determine the following, assuming that there is no friction.

a) What type(s) of mechanical energy does the swimmer possess when she is standing at the edge of the cliff? What is her total mechanical energy at this point?

b) What is the swimmer's total mechanical energy after she has dived and is 3.5 m from the surface, and what type(s) of mechanical energy does she possess at this point?

c) What is the swimmer's total mechanical energy just before she enters the water 7.0 m below her starting point? What type(s) of energy does she possess at this point?

d) What is the swimmer's speed just before she enters the water?

Solution

a) At the top of the cliff, the swimmer's total mechanical energy is in the form of gravitational potential energy.

Conservation of energy states:

$E_T = E_g + E_k$

But, as stated in the problem, the swimmer was not moving, so $E_k = 0$.

$E_T = E_g$

$E_g = mgh$

$E_g = (60.0\ \text{kg})(9.8\ \text{N/kg})(7.0\ \text{m})$

$E_g = 4116\ \text{J} = 4100\ \text{J}$ (using the correct number of significant digits)

Therefore, the swimmer's total mechanical energy is 4100 J.

b) Applying the law of conservation of energy, the swimmer's total mechanical energy halfway down will be the same as it was at the start: 4100 J. At this point, the total mechanical energy will be in the form of gravitational potential energy and kinetic energy.

c) The swimmer's total mechanical energy just before she enters the water will still be equal to 4100 J. This is because the conservation of energy law states that initial total energy equals final total energy. At this point, the total mechanical energy will be entirely in the form of kinetic energy. This is because the swimmer has effectively no height above the water, hence no E_g.

d) $E_{total} = 4116\ \text{J} = E_k$

(Note that you use the unrounded number to reduce rounding error. Also note that there is a maximum of two significant digits in the answer.)

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

$$4116\ \text{J} = \frac{1}{2}(60.0\ \text{kg})v^2$$

$$v = \sqrt{\frac{(2(4116\ \text{J}))}{(60.0\ \text{kg})}}$$

$v = 11.7\ \text{m/s} = 12\ \text{m/s}$

Therefore, the swimmer's speed just as she enters the water is 12 m/s. We can also solve this problem directly using the Law of conservation of energy:

$E_{T_1} = E_{T_2}$

$E_{k_1} + E_{g_1} = E_{k_2} + E_{g_2}$

We know that $E_{k_1} = 0$ and $E_{g_2} = 0$, so $mgh = \frac{1}{2}mv_2{}^2$

Now simply solve.

Example 2

A 2.0 kg textbook slides down a 2.5 m long ramp that makes a 40° angle with the horizontal axis. While sliding, a 1.5 N force of friction acts on the book. What will the book's speed be when it reaches the bottom of the ramp?

Solution

Given:

$m = 2.0$ kg

Length of ramp = $\Delta d = 2.5$ m

$\theta = 40°$

$F_f = 1.5$ N

Required: v_2

Analysis and solution: To proceed, you need the book's initial height. Since the ramp makes a right triangle with the level surface, and with the length of the ramp being the hypothesis and the height being opposite the angle:

Height = (2.5 m)sin40 = 1.6 m

$E_1 = E_2$

$E_{g1} = E_{k2} + E_{th2}$

$mgh_1 = \frac{1}{2}mv_2^{\,2} + F_f\Delta d$

$(2.0 \text{ kg})(9.8 \text{ N/kg})(1.6 \text{ m}) = \frac{1}{2}(2.0 \text{ kg})(v_2)^2 + (1.5 \text{ N})(2.5 \text{ m})$

$31.36 \text{ J} = (1.0 \text{ kg})v_2^{\,2} + 3.75 \text{ J}$

$(1.0 \text{ kg})v_2^{\,2} = 31.36 \text{ J} - 3.75 \text{ J}$

$v_2 = \sqrt{27.61 \text{ J/kg}}$

$v_2 = 5.25$ m/s

Paraphrase: Therefore, the book's speed will be 5.3 m/s when it reaches the bottom of the ramp.

Support Questions

8. A 2.0 kg book initially moving at 4.0 m/s slides to a stop on a level surface. If the book slid a distance of 9.0 m, what was the force of friction acting on the book? Suggested answer

9. Going back to the swimmer example (example 1 in the previous section), determine the swimmer's speed when she was at the 3.5 m mark. (Recall that $m = 60.0$ kg, initial height was 7.0 m, and it was determined that the total initial energy was 4116 J.) Suggested answer

Activity: Energy Skate Park

Open this simulation called Energy Skate Park and familiarize yourself with the program. Try various options and become comfortable with all the features.

Part A

Select the friction parabola track (track selection is at the top of the screen). Set the friction bar to zero by sliding it over. Click on the box called Potential Energy Reference, then drag the dotted line near the bottom of the screen up to the lowest point on the track. Select the pie chart option. Select an object like the skateboarder and position it at the top of the track. Release the object and observe the motion and the pie chart. Try releasing the object from different positions on the track. Make predictions as to what the pie chart will look like at various places on the track. Then, answer the following questions:

1. How does the initial height of the object compare to its final height on the other side of the track? Does it return to the same height? Suggested answer
2. When is the pie chart showing 100% E_p? When is it showing 100% E_k? Describe what is happening between these two extremes. Suggested answer
3. Position the object at a lower point on the track. Does this affect the amount of mechanical energy in the system? Suggested answer
4. Change to a different object. How does mass affect the motion and total mechanical energy? Suggested answer
5. Add friction to the system. Describe what happens to the motion and why. Note the pie chart and the addition of the colour red. How does the percentage of red change with time? Suggested answer
6. If energy cannot be created or destroyed, where did the energy go in the friction case? Suggested answer
7. Change the location of the motion to another celestial object. Repeat the above steps. What effect does changing the value of *g* have on the motion? Suggested answer

Part B

Change the track to Double Well Rollercoaster, then repeat the steps in part A. When does the object have the same

- total mechanical energy?
- kinetic energy?
- potential energy?
- speed?

Suggested answer

Part C (Optional)

Create your own track. Drag the track down using the top left linear track. It will expand as you drag one part of it. Make predictions as to what will happen. For example: when will the rider complete the motion? When will the rider fall off the track? Try the outer space. Create a situation where the rider can actually complete a cycle on the track. What happens to the rider when they reach the end of the track? Why? (Refer to Newton's Laws.)

Suggested answer

Energy Transformations and Electricity

In the introduction to this lesson, electricity generation was discussed. Based on the ideas you have learned in this lesson, you should now understand more about the energy transformations that are involved in the generation of electricity.

Consider hydroelectricity:

- The process begins with water that has gravitational potential energy due to its elevated position.
- In falling, the gravitational potential energy of the water becomes kinetic energy.
- The kinetic energy of the water is transferred to a turbine, which begins to spin.
- Because of a changing magnetic field created by the turning of the turbine, the kinetic energy transforms into the energy of moving electrons: electricity.
- The current electricity travels through the wires and is eventually transformed into another useful form of energy, such as light, sound, or heat.
- A percentage of the energy in the system is converted into thermal energy, due to the friction encountered.

Like all methods of electricity generation, the production of hydroelectricity has its advantages and disadvantages. Hydroelectric generating stations, for example, are expensive to build, but relatively cheap to operate. Hydroelectricity doesn't rely on the use of fossil fuels, so it is environmentally friendly in that it emits only a small amount of greenhouse gas. However, hydroelectric generating stations and dams also destroy environmental habitats and have been shown to cause disruptions in the migratory patterns and habitats of some animals.

Despite its disadvantages, hydroelectricity is still considered to be a "greener" energy resource. It is among the main methods of electricity generation being chosen for further development, in order to help meet Ontario's electricity needs. The following article discusses some of these developments.

184 power producers are given green light

They'll provide Ontario with 2,500 megawatts, more than Niagara Falls

Published on Fri Apr 09 2010
by John Spears
Business Reporter

Donna BigCanoe is looking to see 10 wind turbines sprouting on Georgina Island.

Northland Power will sprinkle solar panels at 13 locations across Ontario, as well as starting a big wind farm and partnering in four hydro projects.

Big and small, their projects were among 184 winners announced Thursday to generate a total of 2,500 megawatts of electricity from renewable sources.

By comparison, the Niagara Falls power plants produce about 2,000 megawatts in total.

The new power will be clean but also more costly.

Ontario Energy Minister Brad Duguid estimated that contracts awarded under the province's green energy legislation will add about $5 a month, or 5 per cent, to a typical power bill by 2012, when the new projects are completed.

(Other factors, such as time-of-use rate and the new HST sales tax, will add even more to power bills.)

Duguid walked a fine line Thursday. On one hand, he played up the announcement as "huge," saying it will prompt investment of $8 billion, create 20,000 jobs and make Ontario a "global green energy leader." But when asked about pricing, he downplayed the scope of the investment.

"Green energy is probably looking at making up 10 per cent or so, maybe a little less than that, of our energy mix over time," he said, as he made the announcement at Durham College's Whitby campus, where turbines twirl on the roof.

"It's not a very large part of our energy mix. So the investments we're making here today are not going to have a huge impact at all on pricing down the road."

Duguid said the province had no choice but to renew dirty and aging generators and the output from any form of new generation—green or not—will cost more than what is produced by the old plants.

In Cornwall, Premier Dalton McGuinty said the announcement, coupled with other green power projects, will help position Ontario to move out of the recession with the green manufacturing prowess to supply international markets, particularly the U.S.

He acknowledged the price increase is "not insignificant," but said it will help eliminate polluting coal-fired plants that contribute to health problems like asthma. "It's hard to put a price tag on that."

The province made two previous awards of green energy contracts—the first for micro-sized generators that could sit on a housetop, the second for mid-sized facilities that might occupy the roof of a supermarket.

Thursday's batch are bigger: Clusters of full-sized wind turbines, or ground-mounted solar facilities that occupy hectares of land.

Their owners will be paid between about 13 cents a kilowatt hour for onshore wind turbines and 44 cents a kilowatt hour for big solar installations. Developments on aboriginal lands get a slight premium. (By comparison, consumers now pay about six cents a kilowatt hour on the energy portion of their bill.)

David Butters, head of the Association of Power Producers of Ontario, welcomed the approvals. "They shoehorned more into the system than we thought they could."

Such new power sources may trigger further need for transmission lines, which often take years to be approved and built.

Environmentalists welcomed the news.

"If you look back 100 years, there were naysayers who said: 'You can't afford to build Niagara Falls'," said Keith Stewart of World Wildlife Fund Canada.

"But we're happy our grandparents built that renewable power facility and we'll be just as happy that we've made these investments today."

Conservative energy critic John Yakabuski accused the Liberals of being "dishonest and misleading" in presenting renewables as a replacement for coal.

Wind and solar power are intermittent, so aren't a real substitute for steady, controllable coal plants, he said.

The Liberals should be working far harder to build new nuclear plants, he said.

Peter Tabuns, of the New Democrats, was happier: "More green jobs in Ontario is a good thing."

He said the flood of applicants shows there is more than enough Ontario renewable power to replace not just coal, but also nuclear plants, so the province "could go much further" than it has.

Meanwhile, Donna BigCanoe looks forward to holding a community meeting to relay the good news.

"As First Nations people, we always think renewable energy is the way to go," she said.

"We don't like peakier plants, nuclear plants. The wind's natural and we can get power from it ... it's a good business proposal for our first nation to make some money that can go back into the community."

The approvals are listed online: The Ontario Power Authority website.

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(20 marks)

17. In the last part of this lesson, energy transformations, as well as advantages and disadvantages associated with hydroelectricity, were discussed. Using this discussion as an example, choose one other form of electrical generation and

- in point form, outline the process through which electricity is generated, highlighting the energy transformations that occur. **(5 marks)**
- state an advantage and a disadvantage for this type of electricity production that have not already been discussed in the lesson. **(2 marks)**
- state the source from which you attained your information. **(1 mark)**

18. **a)** A child on a sled (having a combined mass of 47.0 kg) is pulled by a force directed along a rope that makes a 45° angle with the horizontal axis. The force exerted on the rope is 100.0 N. The force of friction acting on the sled is 30.0 N. If the child is pulled a distance of 10.0 m along a level field, determine the total work done on the child and on the sled. **(3 marks)**

b) Determine the child's final speed at the end of 10.0 m. **(2 marks)**

19. A child on a sled (m = 47.0 kg) slides down a long hill starting from a rest position at a point 10.0 m higher in elevation than his finishing point.

a) What is the total mechanical energy present? **(3 marks)**

b) Assuming that there is no friction and no external pushes, determine the child's speed at the bottom of the hill. **(2 marks)**

c) The child's speed at the bottom of the hill is actually 5.0 m/s. Explain whether or not this defies the law of conservation of energy. **(2 marks)**

Save your answers to the Key Questions in the online submission tool. You'll be able to submit them when you've finished all of the Key Questions for this unit. Now go on to Lesson 6!