Conservation of Energy Law

Energy can neither be created nor destroyed, but it can change from one form to another.

The total amount of energy of a closed system is constant.

Initial energy of a system

+

energy input (+ or –) from outside the system

=

Final energy of a system

$$E_o + Work = E_f$$

(+ or –)

2

Examples of energy conservation

Flashlight turned on, turned off.

Ball rolling along floor to a stop.

Ball dropped from a height, then coming to a stop.

Ball launched upward with a spring launcher, reaching a maximum height, then falling back toward the ground.

Swinging pendulum.

What kind of potential energy powers the following time pieces?

Modern wristwatch.

Old-fashioned pocket watch.

Grandfather clock.

2nd Law of Thermodynamics

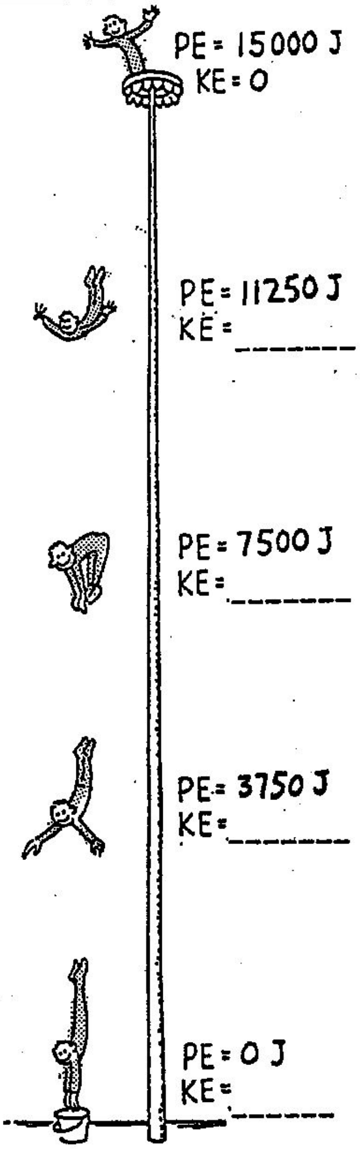
Energy tends to go from ordered forms (potential energy, macroscopic kinetic energy, light energy, etc.) to disordered forms (heat).

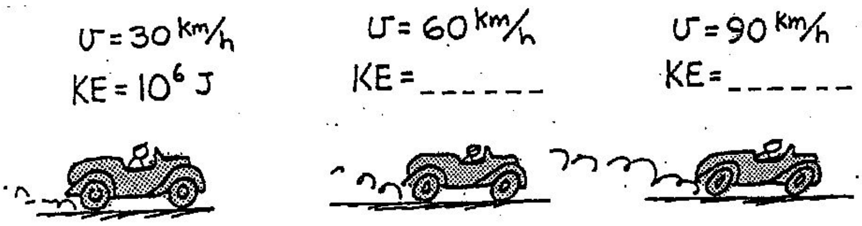
Name ______________________________ Date __________

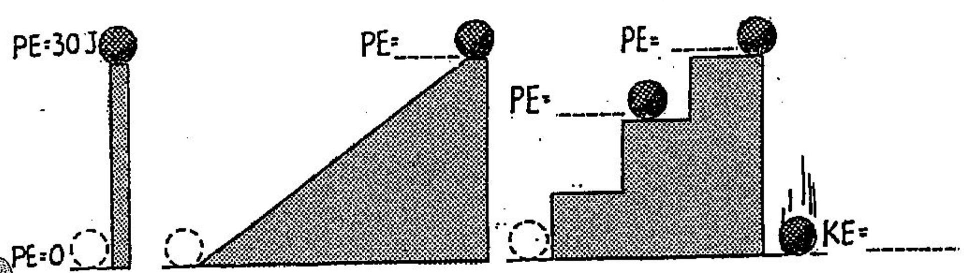
CONCEPTUAL **Physics** PRACTICE SHEET

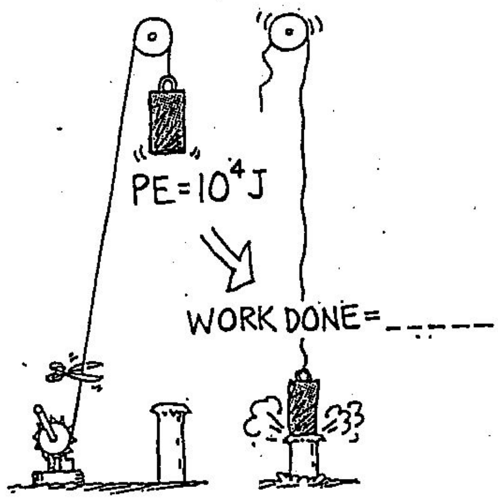
Chapter 6: Energy
Conservation of Energy

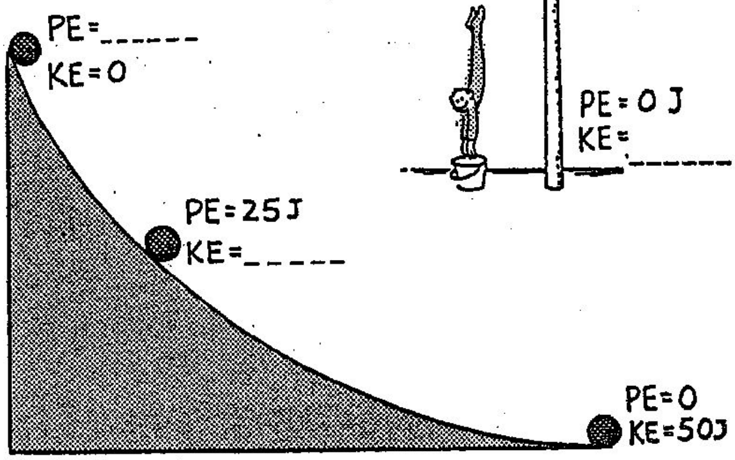
Fill in the blanks for the six systems shown.

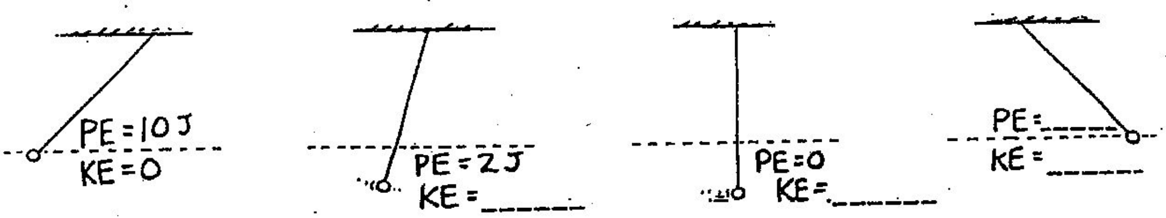












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PHY 111 **Kinetic energy/ Potential energy**

a) The kinetic energy of a moving object is giving by the formula $K = \frac{1}{2}mv^2$.

b) The gravitational potential energy is given by $U_g = mgy$.

Both expressions (*a* and *b*) are expressions of energy and should have the same units (joules). Find the units of each in terms of kg, m and sec.

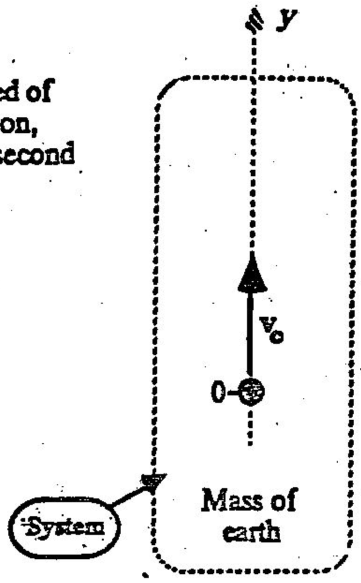
1. What is the kinetic energy of a 6-kg bowling ball with a velocity of 4 m/sec?

2. a) What is the potential energy of a 6-kg bowling ball that is lifted 5 m above the ground?

b) If the bowling ball is dropped, the potential energy is turned to kinetic. Find the speed of the ball just before it hits the floor.

c) Use one of our previous methods to find the speed of an object just before it hits the ground if it dropped from a height of 5m.

A 2.0-kg ball is projected vertically from the origin with an initial speed of 30 m/s. Complete the table below indicating the ball's velocity, position, kinetic energy, gravitational potential energy, and total energy at one-second time intervals. Ignore air resistance and assume that $g = 10\ m/s^2$.
[Hint: Use Newtonian concepts to determine the velocities and the positions. You should be able to determine the velocities in about 20 s if you understand the meaning of acceleration. The displacement during each one-second time interval can be determined easily using the average velocity during that time interval.]



Note that this is a very special problem involving only two types of energy for a system for which no work is done by external forces. The activity is intended to show how energy ideas apply to a very simple system.

time (s)	velocity (m/s)	position (m)	K (J)	U_g(J)	total energy (J)
0	+ 30	0			
1					
2					
3					
4					
5					
6					

6

Kinetic energy of projectile

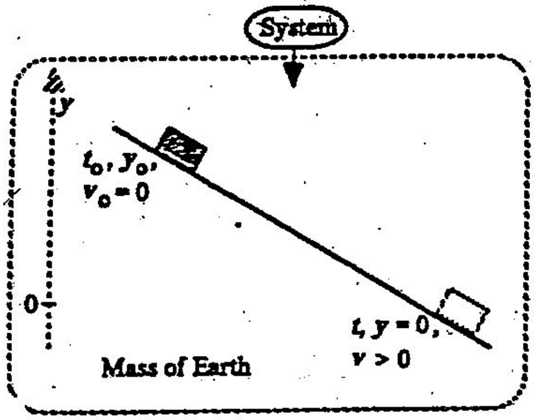
Understanding energy helps us to better understand some things about projectiles without long calculations.

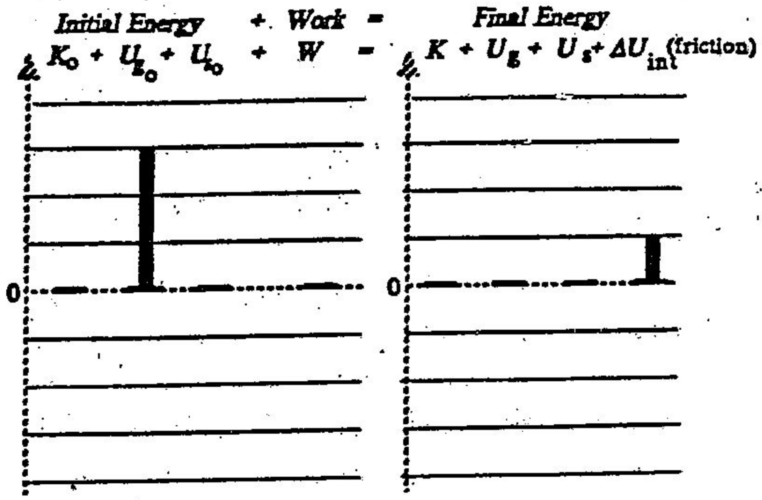
1. A person stands on top of a 45-m high cliff and throws a 500 gram rock forward with a speed of 40 m/sec. What is the speed of the rock when it hits the ground? Use energy.

2. Confirm the answer to problem above using projectile motion concepts. Note that the rock is initially thrown forward in the horizontal direction with a velocity of 40 m/sec. Find the horizontal velocity and vertical velocity of the rock when it hits the ground. Find the speed using the Pythagorean theorem.

PHY 111 **Energy bar chart problems (#1)**

Complete the energy bar chart then solve the problem.





An 8-kg block initially at rest is released from a height of y = 5 meters. At the bottom of the hill its speed is 9 m/s. What is the heat (in joules) generated as it slides down the hill?

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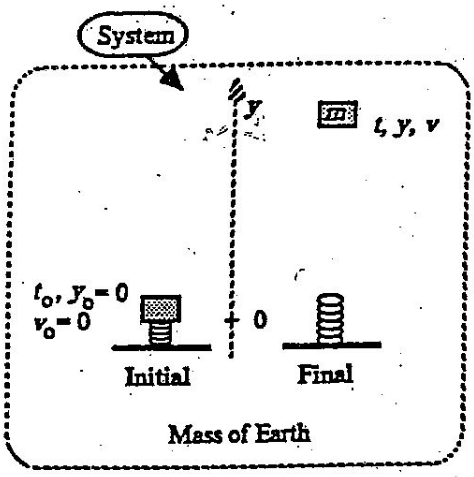
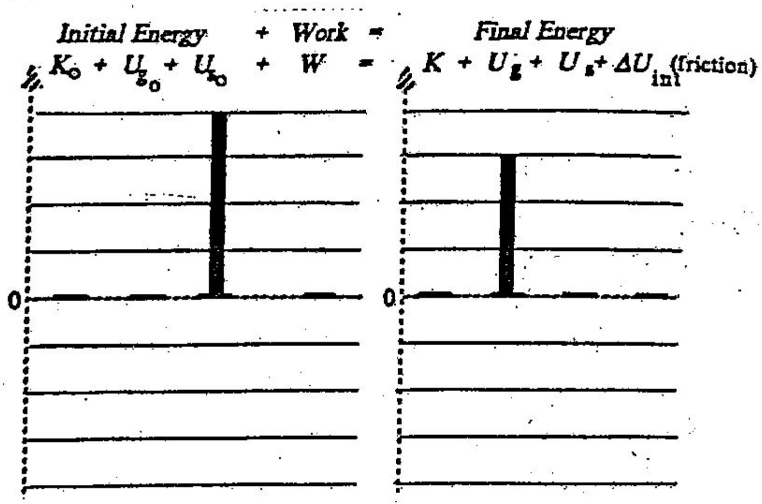
PHY 111 **Energy bar chart problems (#2)**

Complete the energy bar chart then solve the problem.



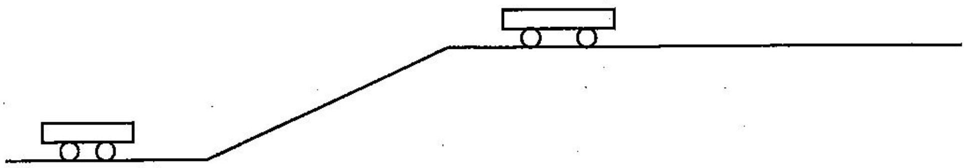


The initial potential energy stored in the spring is 120 joules. The spring is then released and the 4-kg object is shot upward. What is the kinetic energy of the object at the point that the object is 2 meters high? (Ignore friction.) What is the object's velocity at that point?

PHY 111 **Energy Problem**

Show all appropriate work.

1. A 1000-kg is coasting along a level road at 20 m/s. The car comes to a hill and then to another level surface. If the final elevation is 5 meters above the initial elevation, find the velocity of the car on the higher surface. (The car is coasting in neutral the entire time. Ignore friction.) Fill in the bar chart, write a conservation of energy equation and solve for the unknown.

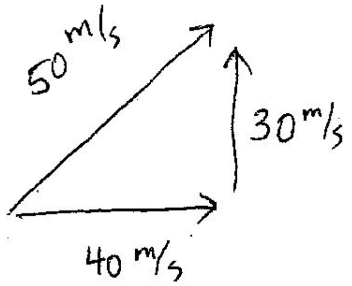


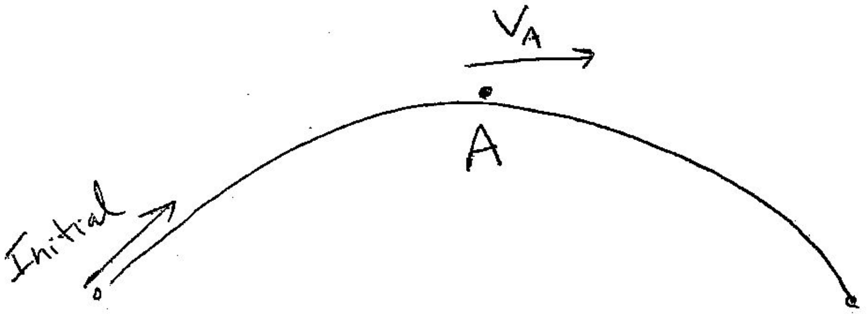
$K_o + U_{go} + U_{so} + Work = K_f + U_{gf} + U_{sf} + Heat$

2. Suppose that, because of friction, 25% of the original kinetic energy of the car is lost to heat as it climbs the hill, find the velocity of the car on the higher surface. Fill in the bar chart, write a conservation of energy equation and solve for the unknown.

$K_o + U_{go} + U_{so} + Work = K_f + U_{gf} + U_{sf} + Heat$

mass of projectile
$m = 10\,kg$





a) How high is point A ? → what is U_g at A?

b) what is V_A? → what is KE at A?

c) what is total energy at A?

d) what is the initial KE?

PHY 111 **Projectile motion and energy**

A 4-kg ball is launched with an initial kinetic energy of 800 J from the ground at an angle of 30°.

a) What is the launch speed of the ball? (Use energy.)

b) Find the initial components of the velocity, v_x and v_y. (Use projectile motion concepts.)

c) Find the maximum height of the ball. (Use projectile motion concepts.)

d) What is the velocity of the ball at the top of its trajectory? (Use projectile motion concepts.)

e) What are the kinetic energy and gravitational potential of the ball at the top of its trajectory?

How does the total energy at the top of the trajectory compare to the initial energy of the ball?

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PHY 111 **Work: A (positive or negative) transfer of energy to an object**

1. A 4-kg object is initially at rest on a frictionless surface. It is pushed to the right with a force of 24 N over a distance of 2 meters. Construct an energy bar chart for this process and solve for the final velocity of the object.

$K_o + U_{go} + U_{so} + \text{Work} = K_f + U_{gf} + U_{sf} + \text{Heat}$

2. A 4-kg object is initially moving to the left on a frictionless surface with a velocity of 6 m/s. It is pushed to the right (opposite the direction of the velocity) with a force of 15 N over a distance of 3 meters; this force does not stop the object, but slows it down.

Draw a motion diagram for the process.

Draw a force diagram.

Construct an energy bar chart for this process and solve for the final velocity of the object.

$K_o + U_{go} + U_{so} + \text{Work} = K_f + U_{gf} + U_{sf} + \text{Heat}$

PHY 111 **Work: Cart Going Uphill**

1. A 20-kg cart is initially at rest at the bottom of a hill. The cart is pushed with a force of 300 N over a distance of 4 m. What is the speed of the cart at the top of the hill?

$K_o + U_{go} + U_{so} + \text{Work} = K_f + U_{gf} + U_{sf} + \text{Heat}$

2. The same cart is pushed with the same force of 300 N over a distance of 4 m, but now the cart has an initial velocity of 10 m/sec. What is the speed of the cart at the top of the hill?

$K_o + U_{go} + U_{so} + \text{Work} = K_f + U_{gf} + U_{sf} + \text{Heat}$

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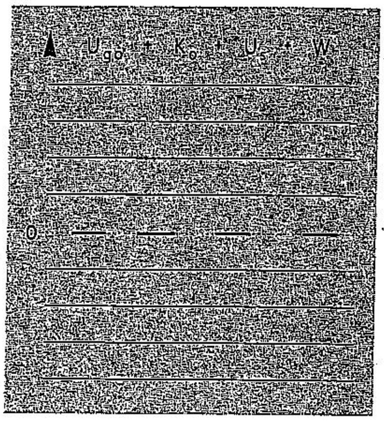
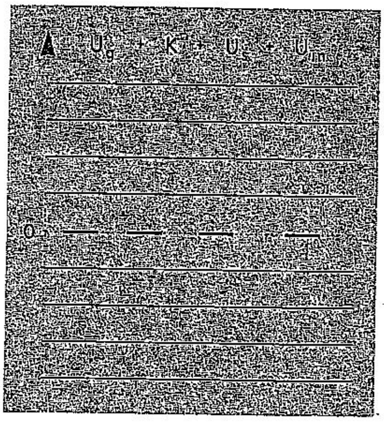
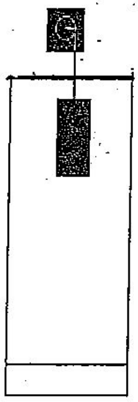
A 60-kg elevator initially moving up at 4.0 m/s slows to a stop in a distance of 4.0 m. Use the generalized work-energy equation to determine the tension in the elevator cable. Assume that the gravitational constant is 10 N/kg.

Question 1: Complete the work-energy bar charts.

Initial Energy + Work = Final Energy







The motor is outside the system doing work on the system.

Question 2: Apply the generalized work-energy equation.

Solve for the cable tension.

PHY 111 **Calculating the heat generated**

Like the formula for work done, the heat generated is also "a force" × "a distance". In particular the force is the force of friction and the distance is the distance over which that friction is applied.

$$\boxed{\text{Heat} = F_{fric} \cdot d}$$

The work is the energy put into a system which is added to the original energy of the system to get the final energy of the system. Therefore the amount of work done is put on the left hand side of our energy equation.

The heat on the other hand is generated throughout the process and is part of the final energy. Therefore the heat generated is put on the right hand side of our energy equation.

Example:

A 4-kg object is moving at a speed of 10 m/sec. The object then encounters a friction force of 40 N that bring the object to a stop.

Fill in the energy bar chart. Find the distance the object travels before it comes to a stop.

$K_o + U_{go} + U_{so} + \text{Work} = K_f + U_{gf} + U_{sf} + \text{Heat}$

Show that the above answer agrees with Newton's 2nd law.

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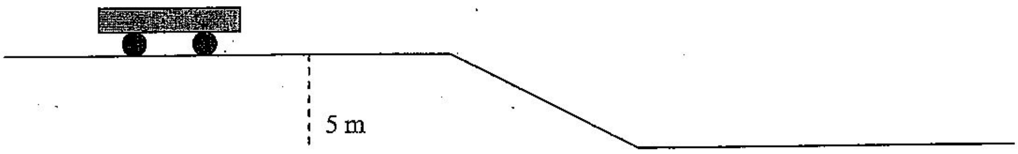
PHY 111 **Energy: Work and heat**

1. a) A 50 kg cart is coasting along the upper surface as shown on the diagram at a speed of 5 m/sec. While the cart is on the upper surface, the cart is given an extra forward push (in the direction of motion) of 200 N over a distance of 1.5 meter. The cart rolls down a ramp with a vertical altitude of 5 m on to a lower surface. What is the speed of the cart on the lower surface? Ignore friction. (First fill in the bar chart.)

Note: The extra forward push at the beginning is considered a force from outside the system.



$K_o + U_{go} + \text{Work} = K_f + U_{gf} + \text{Heat}$

b) Now suppose there is a force of friction on the bottom level only where $\mu = .8$. How far will the cart roll before coming to a stop?

$K_o + U_{go} + U_{chem\,o} + \text{Work} = K_f + U_{gf} + U_{chem\,f} + U_{int}$

PHY 111 **Lifting weights/Power**

Energy conversions: 4.2 joules = 1 calorie 1 Food calorie = 1 kilocalorie = 1000 calories

*A student in the class will lift a 20-lb. weight. How much energy is needed to lift the weight?

mass = 20 lbs. = _______ kg g = 10 m/sec/sec Δy = _________ m

How many joules would it take to lift the weight one time?

* The student will lift the weight as many times as possible during a 15-second interval.

How much power did the student generate?

$$\text{Power} = \frac{\text{Total energy}}{\text{total time}} = \frac{\text{joules}}{\text{second}} = \text{watts}$$

* If the student had instead taken 1 minute to lift the weight the same number of times, what would the power be?

Compare: By taking a minute to do the lifting, the total energy required (increased/ remained same/decreased).

By taking a minute to do the lifting, the power generated (increased/remained same/decreased).

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PHY 111 **Burning off calories**

A certain exercise machine consists of using legs and arms to lift weights by means of ropes and pulleys. The machine is set such that each repetition consists of lifting 60 pounds (27 kg) a distance of 2 feet (60 cm).

a) Find the energy needed (in joules) to do one repetition of the exercise.

b) The exercise is done at a rate of 20 repetitions per minute. At what rate is work being performed (in watts)?

c) Assuming the body is about 17% efficient, at what rate must the body burn energy in order to perform this work (in watts)?

d) Convert the above answer from watts to kcal/hour?

e) A Hostess cupcake consists of 6 grams of fat, 30 grams of carbohydrates, and 2 grams of protein. How many minutes of this exercise would it take to burn off the energy in 1 Hostess cupcake?

The table below lists various activities and the average kilocalories used per hour for each. Obviously this is just a guideline as different people will require more energy for different activities, depending on the size of the person, muscle mass etc. But it is a useful comparative tool.

Type of exercise	Kilocalories used per hour
Aerobics	450
Aqua aerobics	400
Bicycling	450
Cross-country ski machine	500
Eating	85
Golf, with trolley	180
Hiking	500
Jogging, 5 mph	500
Rowing	550
Running	700
Sitting	85
Skipping with rope	700
Sleeping	55
Spinning	650
Standing	100
Step aerobics	550
Squash	650
Swimming	500
Table tennis	290
Tennis	350
Walking, 3 mph	280

Convert 100 kcal/hour to watts.

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PHY 111 Power production: Mini hydroelectric plan

A glass production business built their own hydroelectric generator and sells the excess power to the power grid.

The stream has a flow of 380,000 liters/minute and the water falls a distance of 10 m. (The actual height of the water fall is 7 m and they dug the generator 3 m deeper in order to get more power.)

a) At what rate is potential energy being converted other forms of energy in joules/sec (watts).

b) If the conversion process to electrical energy is 80 % efficient, what is the power production of the mini plant?

PHY 111 Spring constant k: The stiffness of a spring.

Force required to stretch (N)	Length of stretch (m)	$\frac{\text{Force}}{\text{unit length of stretch}}$ (N/m)

• The spring constant is the ratio of the *force* to *the length of stretch* . This ratio should be a "constant". Is it relatively constant? What is the spring constant for this spring?

• How much force would it take to stretch the spring to:

a) 1 meter?

b) 2 meters?

c) 5 centimeters?

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PHY 111 **Spring constant/ spring energy**

a) A spring with an unstretched length of 30 cm is hanging from the ceiling. A 2-kg mass is attached to the spring stretching it to a new length of 50 cm. What is the spring constant?

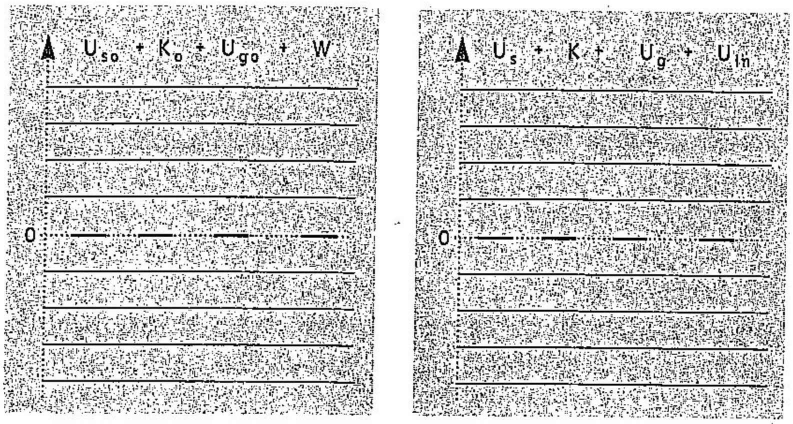
b) Suppose this spring was now placed horizontally on a frictionless table. The 2 kg mass is pushed against the end of the spring compressing the spring 10 cm from its unstretched length. The mass is released and the spring pushes the mass forward. What is the velocity of the mass after it is pushed by the spring?

A 60-kg woman is sitting on a cushioned chair that is attached to a compressed spring and rests on a horizontal floor. The coefficient of kinetic friction between the chair and the floor is 0.10. When the spring is released, the woman is to slide 19.8 m to a glass of water. If she goes too far, she and the glass fall off the floor. If she stops too soon, she misses the glass. Determine the force constant for the spring that will cause her to stop at the glass. The spring is initially compressed 5.0 m, and the gravitational constant is 10N/kg.

Question 1: Complete the work-energy bar charts.

Initial Energy + Work = Final Energy

The friction acts over a distance of 19.8 m.



Question 2: Apply the generalized work-energy equation.	Solve for the magnitudes of the normal and friction forces.

Solve for the desired spring force constant.

Adjust the force constant of the spring to the predicted value and run the simulation to check your answer.