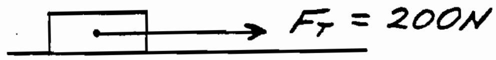
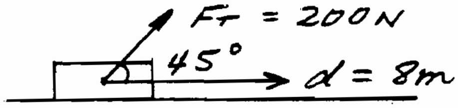
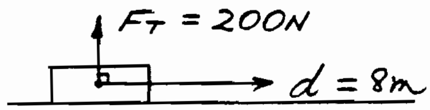
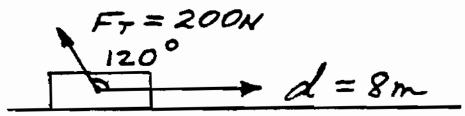
# WORK AND POWER

1. CALCULATE THE WORK DONE BY THE TENSION FORCE:

a) 


b) 


c) 


d) 


BRICK MOVES 8m ALONG X-AXIS IN EACH CASE.

(1600J, 1131J, 0J, −800J)

2. GLENN DRAGS A NEWTON BUSH ALONG THE GROUND WITH A HORIZONTAL FORCE OF 500N. IT MOVES 5m IN 10 SEC. a) HOW MUCH WORK DID HE DO? (2500J) b) HOW MUCH POWER DID HE SUPPLY? (250 WATTS)

3. LIFT-OFF! THE "RIGHT STUFF," TOTAL MASS = 150,000 kg, GOES FROM 0 TO 50 m/s IN .5 SEC. A) CALCULATE THE FORCE OF THE ENGINE. (ASSUME NO $F_f$, ONLY $F_g$.) B) HOW HIGH HAS THE ROCKET GONE? c) HOW MUCH WORK HAS THE ENGINE DONE? d) HOW MUCH POWER DID THE ENGINE SUPPLY?
($1.65 \times 10^7$ N, 12.5 m, $2.0625 \times 10^8$ J, $4.125 \times 10^8$ WATTS)

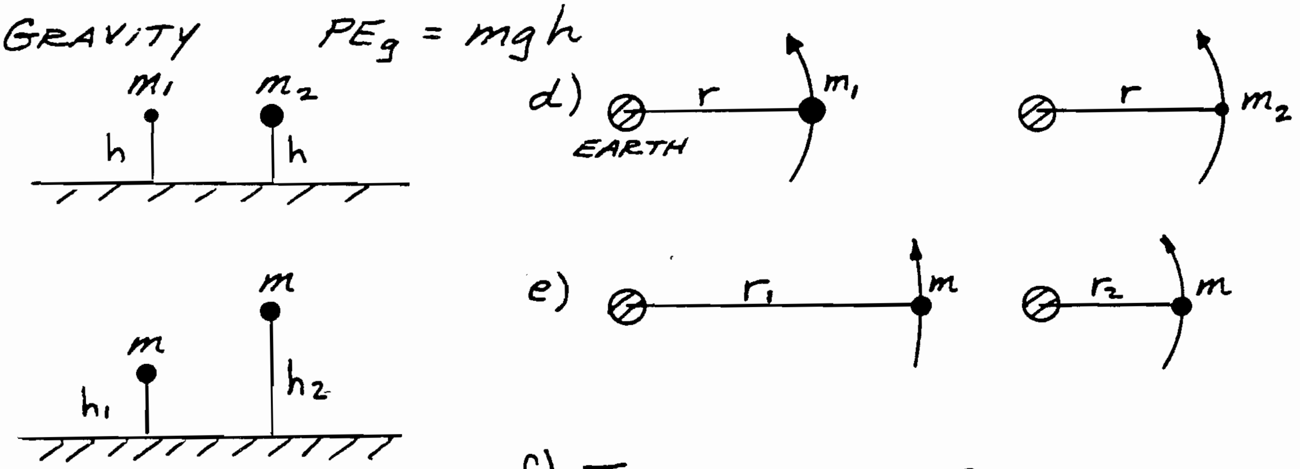
4. SDG AND E SELLS ENERGY FOR 14¢ PER KWATT·HR. HOW MUCH DOES IT COST TO RUN A 60 W BULB FOR ONE DAY? (20.16¢)

# INTUITIONS FOR POTENTIAL ENERGY

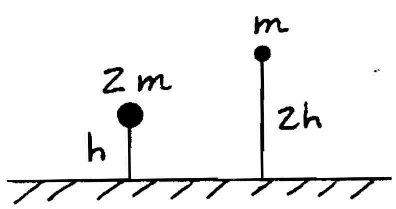
IN EACH SITUATION (a), (b), (c), .... IDENTIFY WHICH CONFIGURATION HAS THE GREATER P.E. : THE ONE ON THE RIGHT, THE LEFT OR ARE THEY EQUAL.

## 1. GRAVITY $PE_g = mgh$

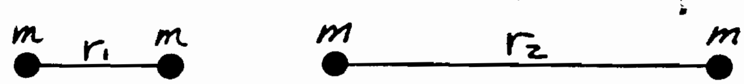
a) b) d) e)




c)



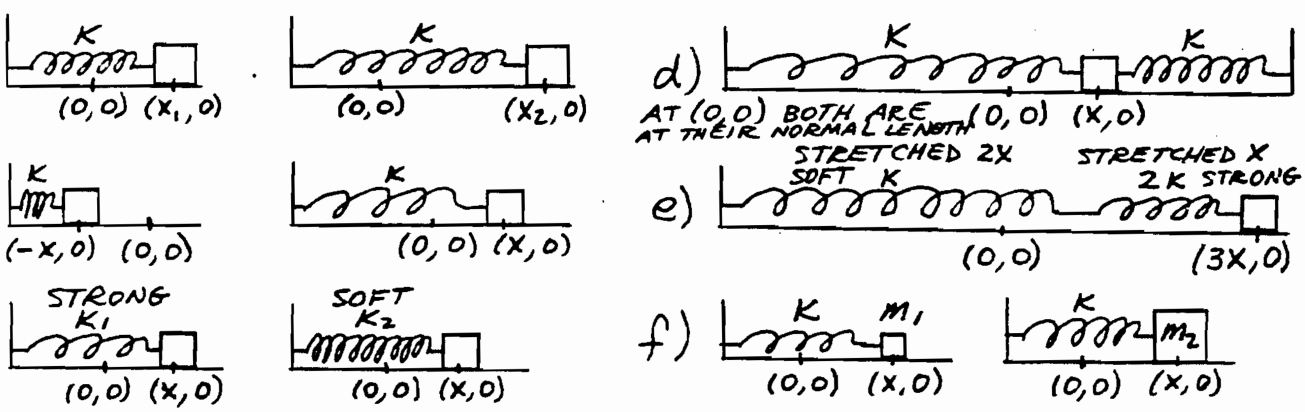

f) THESE MASSES ARE IS OUTER SPACE ALL ALONE.




## 2. SPRINGS $PE_s = \frac{1}{2}kx^2$ STRONG SPRINGS HAVE A LARGE K.

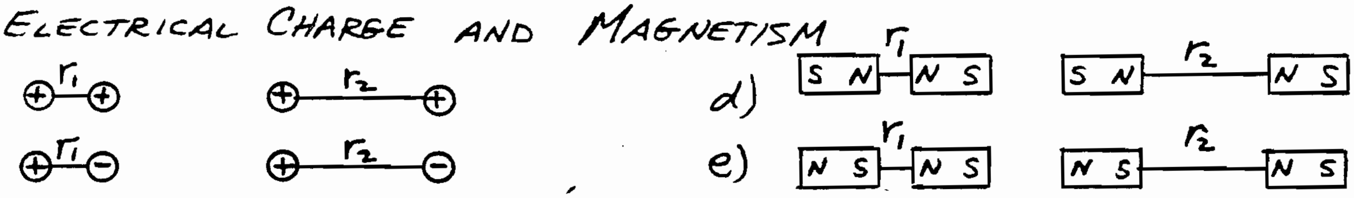
WHICH SPRING HAS MORE POTENTIAL ENERGY?

a) b) c) d) e) f)

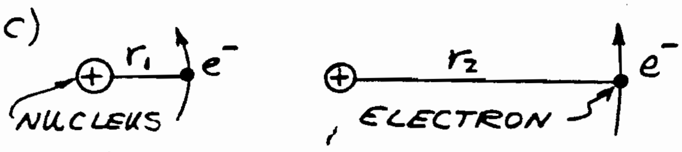



## 3. ELECTRICAL CHARGE AND MAGNETISM

a) b) d) e)




c)




ANSWERS: RIGHT, RIGHT, EQUAL, LEFT, LEFT, RIGHT; RIGHT, =, L, =, L, =; L, R, R, L, R

CONSERVATION OF ENERGY

1. JULIAN, WHOSE MASS IS 72 KG, IS PERCHED ATOP RENDEZVOUS PEAK, WHOSE ELEVATION IS 4000 m. JULIAN NOW ZOOMS DOWN THE FRICTIONLESS SLOPE TO THE CHALET, WHOSE ELEVATION IS 2720 m. FIND HIS SPEED AS HE FLIES BY THE HUT. (160 m/s)

2. DANIEL, WHOSE MASS IS 60 KG, STANDS ATOP THE VOLCANIC CLIFFS OF MAUI, WHICH ARE 45 m ABOVE THE OCEAN. DANIEL LEAPS UPWARD WITH AN INITIAL SPEED OF 16 m/s AS HE DIVES OUTWARD AND DOWN TO THE SEA. FIND THE SPEED WITH WHICH HE STRIKES THE WATER. (34 m/s)

3. MICHELE, WHOSE MASS IS 50 KG, RIDES THE CHAIR-LIFT FROM THE HUT IN ZERMATT TO THE SUMMIT OF THE MATTERHORN. STARTING AT ELEVATION 900 m, THE LIFT CARRIES HER UP TO ELEVATION 4500 m IN TWENTY MINUTES. THE ENGINE FOR THE LIFT HAS AN EFFICIENCY OF 30%. FIND:

a) THE WORK REQUIRED TO CARRY HER. ($1.8 \times 10^6$ J)

b) THE REQUIRED POWER. (1500 WATTS)

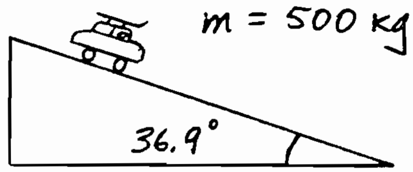
c) THE SIZE OF ENGINE REQUIRED FOR THE LIFT. (5000 W)

4. A CONVEYOR BELT TRANSPORTS EIGHTEEN BALES OF HAY PER MINUTE TO THE LOFT OF THE BARN, WHOSE ELEVATION IS 12 m. EACH BALE HAS A MASS OF 32 KG. FIND: a) THE TOTAL WORK DONE ON THOSE BALES b) POWER (69120 / 1152)

5. SARAH, m = 50 KG IS CRUISING AT 20 m/s WITH HER X-C SKIS ALONG FRICTIONLESS, HORIZONTAL SNOW. SHE HITS A ROUGH SPOT WITH FRICTION, WHICH REDUCES HER SPEED TO 8 m/s OVER A DISTANCE OF 28 m. FIND: a) THE WORK DONE BY FRICTION, b) $F_f$, c) $F_N$, d) $\mu$. (8400, 300, 500, .6)

6. TOM TOSSES A LACROSSE BALL STRAIGHT UP WITH AN INITIAL SPEED OF 15 m/s. WHEN IT RETURNS TO HIS HAND, THE BALL, WHOSE MASS IS .18 KG, IS ONLY TRAVELING AT 9 m/s. a) HOW MUCH ENERGY WAS LOST TO FRICTION OVER THE ENTIRE TRIP?
b) IF HALF OF THIS ENERGY IS LOST ON THE WAY UP, HOW HIGH DOES THE BALL GO? c) ASSUMING $F_f$ IS CONSTANT, CALCULATE ITS VALUE. (12.96 J, 7.65 m, .847 N)

7. LORRAINE IS DRIVING HER NEW BMW, WITH SUNROOF AND SKI RACK, TO THE FAR NORTH. AT THE TOP OF THE HILL, SHE IS TRAVELING AT 30 m/s. A CHOCOLATE MOOSE AHEAD! LORRAINE BRAKES AND 50 m LATER SHE IS TRAVELING AT 27 m/s.




m = 500 kg

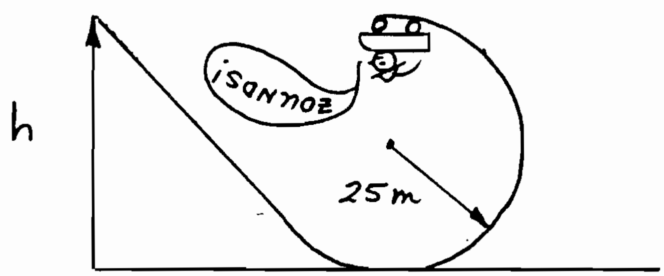
A) SINCE LORRAINE SLOWED DOWN, THERE MUST BE FRICTION. CALCULATE THE WORK DONE BY $F_f$. (192,750 J)

B) CALCULATE $F_f$ (3855 N)  c) CALCULATE $\mu$. (.964)

8. AHHH! TARZAN, 60 kg, IS ATOP A 50 m CLIFF. JANE IS IN TROUBLE. TARZAN SWINGS DOWN AND SNATCHES HER FROM THE LION'S JAWS.


A) HOW FAST IS TARZAN MOVING AT THE BOTTOM OF THE CLIFF? B) WHY IS THERE NO P.E. ASSOCIATED WITH THE $F_T$? c) WHAT IS $F_T$ IN THE VINE JUST BEFORE HE GRABS JANE? d) JANE'S MASS IS 40 kg. HOW FAST ARE THEY GOING AFTER THE COLLISION?
e) WHAT IS $F_T$ NOW? f) HOW HIGH DO THEY SWING?
(ANSWERS: 31.62 m/s, 1800 N, 18.97 m/s, 1720 N, 18 m)

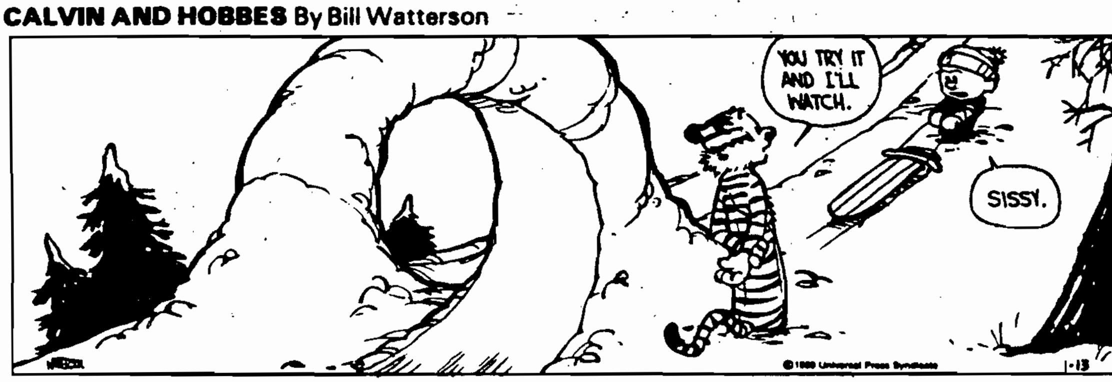
9. FOR #80/HR, YOU ARE TO DESIGN A ROLLER COASTER SO THAT PASSENGERS WILL FEEL WEIGHTLESS AT THE HIGHEST POINT. CALCULATE THE HEIGHT AT WHICH THE CAR SHOULD START AT REST SO THAT THE RIDERS JUST BARELY LEAVE THEIR SEATS FOR A THRILL/MINUTE!




LET $m$ = MASS AND WATCH IT CANCEL.

(62.5m)

CALVIN AND HOBBES By Bill Watterson




10. CHIHIRO'S 3200 KG CADILLAC SEVILLE ACCELERATES UNIFORMLY FROM 0 TO 30 m/s IN 5 SECONDS.

A) CALCULATE THE TOTAL WORK DONE BY THIS POWERFUL AUTOMOBILE. ($1.44 \times 10^6$ J)

B) CALCULATE THE AVERAGE POWER OVER THE FIVE SECOND INTERVAL. ($2.88 \times 10^5$ WATTS)

C) CALCULATE THE CAR'S ACCELERATION. FIND ITS VELOCITY AFTER 3 SECONDS ($6\,m/s^2$, $18\,m/s$)

D) CALCULATE THE INSTANTANEOUS POWER AT THIS THIRD SECOND. ($3.456 \times 10^5$ WATTS)

## Important Terms

**Work** is a measure of the change (in a general sense) a force gives rise to when it acts upon something. When a body undergoes a displacement while a force acts on it, the work done by the force is equal to the product of the displacement and the component of the force in the direction of the displacement. In the SI system the unit of work is the **joule** and in the British system it is the **foot-pound**.

The rate at which work is done is called **power**. The unit of power in the metric system is the **watt**, which is equal to 1 J/s, and in the British system it is the **ft·lb/s**. The **horsepower** is a unit of power equal to 550 ft·lb/s, which is 746 watts.

**Energy** is that which may be converted into work. When something possesses energy, it is capable of performing work or, in a general sense, of accomplishing a change in some aspect of the physical world. The units of energy are those of work.

The three broad categories of energy are **kinetic energy**, which is the energy something possesses by virtue of its motion; **potential energy**, which is the energy something possesses by virtue of its position in a force field; and **rest energy**, which is the energy something possesses by virtue of its mass.

The principle of **conservation of energy** states that the total amount of energy in a system isolated from the rest of the universe always remains constant, although energy transformations from one form to another, including rest energy, may occur within the system.

## Important Formulas

*Work:*

$$W = Fs \cos \theta$$

*Work in lifting object:*

$$W = wh = mgh$$

*Power:*

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

*Kinetic energy:*

$$KE = \tfrac{1}{2}mv^2$$

*Gravitational potential energy:*

$$PE = wh = mgh$$

*Rest energy:*

$$E_0 = m_0c^2$$

## Multiple Choice

1. According to the principle of conservation of energy (with energy interpreted as including rest energy), energy can be
   a. created but not destroyed.
   b. destroyed but not created.
   c. both created and destroyed.
   d. neither created nor destroyed.
2. A golf ball and a ping-pong ball are dropped in a vacuum chamber. When they have fallen half way down, they have the same
   a. velocity. b. potential energy.
   c. kinetic energy. d. rest energy.
3. In the formula $E = mc^2$, the symbol $c$ represents
   a. the velocity of the body.
   b. the velocity of sound.
   c. the velocity of light.
   d. the rest energy of 1 kg of matter.
4. One horsepower is not equal to
   a. 550 ft-lb/s. b. 33,000 ft-lb/min.
   c. 746 J. d. 0.746 kW.
5. Which of the following is not a unit of energy?
   a. joule b. foot·pound
   c. watt-hour d. newton
6. Which of the following is not a unit of power?
   a. joule·s b. watt
   c. ft·lb/min d. horsepower
7. To keep a vehicle moving at the speed $v$ requires a force $F$. The power required is
   a. $Fv$. b. $\frac{1}{2} Fv^2$.
   c. $F/v$. d. $F/v^2$.
8. A 2-lb book is held 4 ft above the floor for 50 s. The work done is
   a. 0. b. 8 ft·lb.
   c. 12.5 ft·lb. d. 400 ft·lb.
9. A 100-lb boy runs up a staircase to a floor 15 ft higher in 5.45 s. His power output is
   a. 1/64 hp. b. 1/2 hp.
   c. 1 hp. d. 275 hp.
10. A 1-kg mass has a potential energy of 1 joule relative to the ground when it is at a height of
    a. 0.102 m. b. 1 m.
    c. 9.8 m. d. 32 m.
11. A 1-N weight has a potential energy of 1 joule relative to the ground when it is at a height of
    a. 0.102 m. b. 1 m.
    c. 9.8 m. d. 32 m.
12. A 1-slug mass has a potential energy of 1 ft·lb relative to the ground when it is at a height of
    a. 0.031 ft. b. 1 ft.
    c. 9.8 ft. d. 32 ft.
13. A 1-lb weight has a potential energy of 1 ft·lb relative to the ground when it is at a height of
    a. 0.031 ft. b. 1 ft.
    c. 9.8 ft. d. 32 ft.
14. A total of 4900 joules is expended in lifting a 50-kg mass. The mass was raised to a height of
    a. 10 m.
    b. 98 m.
    c. 960 m.
    d. 245,000 m.
15. A 16-slug mass is lifted to a height of 10 ft. Its potential energy is
    a. 5 ft·lb. b. 20 ft·lb.
    c. 160 ft·lb. d. 5120 ft·lb.
16. A 1-kg mass has a kinetic energy of 1 joule when its speed is
    a. 0.45 m/s. b. 1 m/s.
    c. 1.4 m/s. d. 4.4 m/s.

## Exercises

1. Under what circumstances (if any) is no work done on a moving body even though a net force acts upon it?
2. Does every moving body possess kinetic energy? Does every stationary body possess potential energy? Can something possess both kinetic and potential energy?
3. At what point in its motion is the kinetic energy of a pendulum bob a maximum? At what point is its potential energy a maximum?
4. Is kinetic energy a scalar or a vector quantity? Is potential energy a scalar or a vector quantity?
5. The potential energy of a golf ball in a hole is negative relative to the ground. Under what circumstances (if any) is its kinetic energy negative? Its rest energy?
6. Electrical energy is usually reckoned by utility companies in kilowatt-hours (kWh). How many joules are there in a kWh?
7. Four thousand joules are used to lift a 30-kg mass. If the mass is at rest before and after its elevation, how high does it go? (13.33 m)
8. A man holds a 10-kg package 1.2 m above the ground for 1 min. How much work does he perform?
9. A centripetal force of 18 N is used to keep a 2-kg ball in uniform circular motion at the end of a string 1 m long. How much work does the force do in each revolution of the ball? (0)
10. The sun exerts a force of $4 \times 10^{28}$ N on the earth, and the earth travels $9.4 \times 10^{11}$ m in its annual orbit of the sun. How much work is done by the sun on the earth in the course of a year?
11. (a) A force of 130 N is used to lift a 12-kg mass to a height of 8 m. How much work is done by the force? (b) A force of 130 N is used to push a 12-kg mass on a horizontal, frictionless surface for a distance of 8 m. How much work is done by the force?
12. A 20-kg wooden box is pushed a distance of 15 m on a horizontal stone floor by a force just sufficient to overcome the friction between box and floor. The coefficient of friction is 0.4. (a) What is the required force? (b) How much work does the force do?
13. An 80-kg man climbs a mountain 3000 m high in 10 hr. (a) How much work does he perform? (b) What is his average power output in watts? In hp? $(2.4 \times 10^6$ J) (166.7 WATTS, .0894 HP)
14. A 120-lb woman climbs a mountain 8000 ft high in 8 hr. (a) How much work does she perform? (b) What is her average power output in ft-lb/s? In hp?
15. In 1970 approximately $2 \times 10^{20}$ joules of work were performed throughout the world by inanimate devices of all kinds, perhaps 15 times as much as the muscle power provided in that year. The work was used for heat, light, transport, manufacturing, and so forth. About 98% of the work was ultimately derived from the fossil fuels coal, natural gas, and oil, the rest mainly from water power with a small (0.25% of the total) contribution from nuclear power stations. (a) Express the power consumption in 1970 in watts. (b) Find the average power consumption per person in watts and in hp on the assumption that the world's population in 1970 was $3.5 \times 10^9$.
16. A white horse has a power output of 1 hp. What is the maximum force it can exert at a velocity of 3 m/s? (249 N)
17. The anchor windlass of a boat must be able to raise a total load (anchor plus chain) of 800 kg at a velocity of 0.5 m/s. What should the minimum rating of the motor be, in kW? (4 kW)
18. At its cruising velocity of 520 mi/hr, the two engines of a DC-9 airplane produce a thrust of 11,400 lb each. How many hp does each engine develop under these circumstances? (15808 HP)
19. Each of the four engines of a DC-8 airplane develops 7500 hp when the cruising velocity is 240 m/s. How much thrust does each engine produce under these circumstances? (23312 N)
20. A motorboat requires 160 hp to move at the constant velocity of 8 m/s. How much resistive force does the water exert on it at that velocity? (14920 N)
21. Is more work needed to bring a car's velocity from 10 mi/hr to 20 mi/hr or from 50 mi/hr to 60 mi/hr?
22. Find the kinetic energy of a 256-lb ostrich running at 50 ft/s. (10000 ft-lbs)
23. A 3200-lb car is moving at 40 mi/hr. What is its kinetic energy?
24. A 0.02-kg bullet has a velocity of 500 m/s. What is its kinetic energy? (2500 J)
25. Find the average kinetic energy of a 70-kg sprinter who covers 400 m in 45 s. (2765 JOULES)
26. A 90-kg pole vaulter clears the bar at a height of 5 m. Find his potential energy at this height. (4500 J)
27. A 160-lb diver stands on a diving board 20 ft above the surface of a lake. What is his potential energy with respect to the surface? (3200 ft-lbs)
28. A boy slides down a sliding pond from a starting point 10 ft above the ground. His velocity at the bottom is 12 ft/s. What percentage of his initial potential energy was dissipated?
29. A man skis down a slope 100 m high. His velocity at the foot of the slope is 20 m/s. What percentage of his initial potential energy was dissipated? (80%)
30. A 3-kg stone is lifted to a height of 100 m and then dropped. What is its kinetic energy when it is 50 m from the ground? (1500 JOULES)
31. A 2-kg ball is at rest when a horizontal force of 5 N is applied. In the absence of friction, what is the speed of the ball after it has gone 10 m? (7.07 m/s)
32. A force of 500 newtons is used to lift a 20-kg object to a height of 10 m. There is no friction present. (a) How much work is done by the force? (b) What is the change in the potential energy of the object? (c) What is the change in the kinetic energy of the object? (5000, 2000, 3000)
33. At her highest point, a 40-kg girl on a swing is 2 m from the ground while at her lowest point she is 0.8 m from the ground. What is her maximum speed? On another swing a 50-kg boy undergoes

exactly the same motion. What is his maximum speed?

34. The source of the sun's energy (and therefore, directly or indirectly, of nearly all energy available to man) is the conversion of hydrogen to helium. As described later in the book, the nuclei of four hydrogen atoms, each of mass $1.673 \times 10^{-27}$ kg, join together in a series of separate reactions to yield a helium nucleus of mass $6.646 \times 10^{-27}$ kg. How much energy is liberated each time a helium nucleus is formed? How many helium nuclei are formed to produce the $10^7$ J a moderately active person requires per day?

35. Sunlight falls on the earth at the rate of 1400 watts/m². Express this figure in hp/ft².

## Problems

1. A horse is towing a barge with a rope that makes an angle of 20° with the canal. If the horse exerts a force of 400 N, how much work does it do in moving the barge 1 mile? ($6.014 \times 10^5$ J)

2. A man pulls a 150-lb crate for 80 ft across a level floor using a rope that is 30° above the horizontal. If the coefficient of friction between crate and floor is 0.30 and the man uses just enough force to move the crate without accelerating it, how much work does he perform? (Assume the rope is attached to the center of gravity of the crate.)

3. A boy pulls a sled with a force of 10 lb for 100 ft. The rope attached to the sled is at an angle of 30° above the horizontal. (a) How much work is done? (b) If the boy moves the sled 100 ft in 45 s, find his power output in horsepower.

4. A horizontal force of 5 N is used to push a box up a ramp 5 m long that is at an angle of 15° above the horizontal. How much work is done? (24.15 J)

5. Two men set out to climb to the summit of a 3000-m mountain starting from sea level. One of them sets out along a slope that averages 30° above the horizontal, the other along a slope that averages 40° above the horizontal. Each man has a mass of 80 kg and carries a 10-kg knapsack. Find the work done by each of them. ($2.7 \times 10^6$ J)

6. A 160-lb man carrying a 32-lb knapsack climbs to the summit of a 16,000-ft mountain. The average slope of the mountain is 40°. If he starts from a base camp at an altitude of 8000 ft, how much work does he perform in making the ascent?

7. An escalator carries passengers from one floor of a building to another 35 ft higher. It is designed to have a capacity of 200 passengers per minute, assuming an average weight per passenger of 150 lb. Find the required horsepower of the motor if half the work it does is dissipated as heat. (63.6)

8. A 15-hp motor is used to hoist a 1-ton bucket of concrete to the twentieth floor of a building under construction, a height of 300 ft. If no power is lost, how much time is required for the ascent?

9. In 1932 five members of the Polish Olympic ski team climbed from the 5th to the 102nd floor of the Empire State Building, a distance of approximately 1000 ft, in 21 min. One of these men weighed 165 lb. How many horspower did he develop in the ascent? (.238 HP EACH)

10. Thirty horsepower is required to propel a 3600-lb car at 25 mi/hr on a horizontal road. (a) How much resistance must the car overcome at this speed? (b) How much power is required for the car to ascend an 8° hill at the same speed?

11. A man uses a rope and system of pulleys to lift a 160-lb object to a height of 5 ft. He exerts a force of 45 lb on the rope and pulls a total of 20 ft of rope through the pulleys in the course of lifting the object, which is at rest afterward. (a) How much work does the man do? (b) What is the change in the potential energy of the object? (c) If the answers to (a) and (b) are different, explain.

12. A man uses a rope and system of pulleys to lift an 80-kg object to a height of 2 m. He exerts a force of 220 N on the rope and pulls a total of 8 m of rope through the pulleys in the course of raising the object, which is at rest afterward. (a) How much work does the man do? (b) What is the change in the potential energy of the object? (c) If the answers to (a) and (b) are different, explain.

13. A force of 100 lb is used to lift an 80-lb weight to a height of 20 ft. There is no friction present. (a) How much work is done by the force? (b) What is the change in the potential energy of the weight? (c) What is the change in the kinetic energy of the weight? (2000, 1600, 400 ft·lbs)

14. (a) A force of 8 N is used to push a 0.5-kg ball over a horizontal, frictionless table a distance of 3 m. If the ball starts from rest, what is its final kinetic energy? (b) The same force is used to lift the same ball a height of 3 m. If the ball starts from rest what is its final kinetic energy?

15. A waterfall is 30 m high and $10^4$ kg of water flows over it per second. (a) How much power does this flow represent? (b) If all this power could be converted to electricity, how many 100-watt light bulbs could be supplied? ($3 \times 10^6$ WATTS, $3 \times 10^4$ BULBS)

16. A ball is dropped from a height of 1 m and loses 10% of its kinetic energy when it bounces on the ground. To what height does it rise?

17. In the operation of a certain pile driver, a hammer weighing 1000 lb is dropped from a height of 19 ft above the head of a pile. If the pile is driven 0.5 ft into the ground with each impact of the hammer, what is the average force on the pile when struck?

$3.9 \times 10^4$ lbs.

## Answers to Multiple Choice

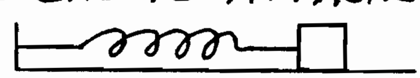
| | | |
|---|---|---|
| 1. d | 9. b | 17. d |
| 2. a | 10. a | 18. c |
| 3. c | 11. b | 19. d |
| 4. c | 12. a | 20. b |
| 5. d | 13. b | 21. b |
| 6. a | 14. a | 22. c |
| 7. a | 15. d | 23. a |
| 8. a | 16. c | 24. a |

# SPRINGS: HOOKE'S LAW AND CONSERVATION OF ENERGY

1. A SPRING, WHOSE UNSTRETCHED LENGTH IS .25 m, IS HUNG VERTICALLY FROM THE CEILING. A 12 KG GRANITE ROCK IS ATTACHED TO THE LOWER END OF THE SPRING, WHOSE TOTAL LENGTH IS NOW .65 m. FIND THE SPRING CONSTANT. (300 N/m)

2. IN THE PRODUCE SECTION AT THE RALPHS, BARBI PLACES A SIX POUND BAG OF GALA APPLES IN THE PAN OF THE SCALE, WHICH DROPS 3/4" FROM ITS EQUILIBRIUM POSITION. A) FIND K. (8 lb/IN, 96 lb/ft) B) BARBI REMOVES THE APPLES AND REPLACES THEM WITH A SACK OF IRISH O'RANGES. THE SCALE NOW DROPS $2\frac{1}{2}$" FROM ITS EQUILIBRIUM POSITION. FIND THE WEIGHT AND THE MASS OF THE CITRUS. (20 lbs, .625 SLUGS)

3. A SPRING, WITH AN UNSTRAINED LENGTH OF .8 m AND A SPRING CONSTANT OF 50,000 N/m, SITS VERTICALLY AT THE BOTTOM OF THE ELEVATOR SHAFT IN ROBINSONS-MAY. THE 1250 KG ELEVATOR NOW COMES TO REST ON THE SPRING WHILE THE ELEVATOR CABLES GO SLACK. FIND THE FINAL LENGTH OF THE SPRING. (.55 m)

4. A HORIZONTAL SPRING, WHOSE CONSTANT IS 200 N/m, IS FIXED AT ONE END. THE FREE END IS ATTACHED TO AN 8 KG FRICTIONLESS BRICK : 
THE SPRING IS INITIALLY STRETCHED 30 m PAST ITS EQUILIBRIUM POSITION. FIND THE INITIAL: A) FORCE EXERTED ON THE MASS (−6000 N) B) POTENTIAL ENERGY (90000 J) THE MASS IS NOW RELEASED FROM REST AND IT OSCILLATES BACK AND FORTH BETWEEN 30 AND −30 m. FIND: A) THE MAXIMUM SPEED OF THE MASS (150 m/s) B) THE SPEED OF THE MASS AT X = 24 m (90 m/s)

c) THE MASS' POSITION WHEN ITS SPEED IS 120 m/s. (± 18 m)

D) THE P.E. WHEN THE KE. IS 20000 J (70000 J)

E) THE SPEED AT $X = 15$ m (129.9 m/s)

F) THE POSITION AT $V = 75$ m/s (± 25.98 m)

G) THE SPEED AND THE LOCATION OF THE MASS WHEN THE P.E. EQUALS THE K.E. (106 m/s, ± 21.21 m)

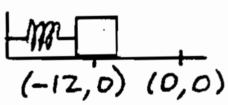
5. WILLIAM TELL, OF OVERTURE FAME, PULLED THE STRING OF HIS CROSSBOW BACK .75 m WITH A FORCE OF 300N. THE ARROW'S MASS WAS .015625 KG. FIND:

A) THE SPRING CONSTANT FOR THE BOW. (400 N/m)

B) THE INITIAL P.E. OF THE BOW. (112.5 JOULES)

c) THE SPEED OF THE BOLT AS IT LEFT THE BOW. (120 m/s)

6. A HORIZONTAL SPRING WITH $K = 50$ N/m HAS A 15 KG MARBLE BLOCK AT THE FREE END. HOWEVER, THE BLOCK IS <u>NOT</u> ATTACHED PERMANENTLY TO THE SPRING. FURTHER, THE BLOCK HAS FRICTION WITH THE FLOOR, WHOSE COEFFICIENT, $\mu$, EQUALS .8.



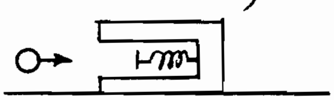

WE PUSH THE BRICK TO THE LEFT COMPRESSING THE SPRING 12 m. NOW, WE RELEASE THE BRICK FROM REST. FIND: A) THE TOTAL DISTANCE TRAVELED BY THE BRICK UNTIL IT STOPS. (30) B) ITS FINAL LOCATION. (18,0)

7. THE MARBLE BRICK IS NOW PERMANENTLY ATTACHED TO THE SPRING. AGAIN, WE COMPRESS THE SPRING 12 m AND RELEASE THE BLOCK FROM REST. THE MASS OSCILLATES BACK AND FORTH AS ITS AMPLITUDE DECAYS. FINALLY, DUE TO THE FRICTION, THE MASS COMES TO REST AT THE ORIGIN. FIND THE TOTAL DISTANCE TRAVELED. (30 m)

8. KILLER, MY CANINE, CONTINUALLY ATTACKED THE MAIL CARRIER. "CEASE AND DESIST!" I COMMANDED. TO REINFORCE MY REQUEST, I TIED HIM, KILLER THAT

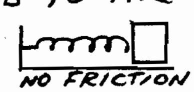
IS, TO A SPRING WHOSE CONSTANT WAS 200 N/m. THE NEXT TIME THE POSTAL WORKER ARRIVED, KILLER, WHOSE MASS IS 15 KG, SPRANG INTO ACTION! KILLER RAN 4m PAST THE SPRING'S EQUILIBRIUM POINT AND STOPPED WHILE CHEWING ON THE MAIL CARRIER'S TIBIA. FIND KILLER'S P.E. AS HE ATE LUNCH. (1600 J) ESCAPE! THE USPS CARRIER SPRAYED LOC TITE® ON KILLER'S LIPS. OOPS! SOME OF THE GLUE GOT ON KILLER'S FUR, WHICH GENERATED A FRICTION FORCE OF 100N AS THE SPRING DRAGGED KILLER BY TOWARD MY HOME. FIND: A) KILLER'S SPEED AT THE EQUILIBRIUM POINT (12.6 m/s) B) KILLER'S SPEED WHEN THE SPRING HAS BEEN COMPRESSED 2 m. (8.94 m/s) C) KILLER'S LOCATION AT WHICH HE STOPS MOVING BACKWARDS. (−3, 0) D) THE TOTAL DISTANCE THAT KILLER SKIDDED BACK TOWARD MY ABODE. (7 m)

9. A CANNON BALL CATCHER, WHOSE MASS IS 80 KG AND WHOSE SPRING CONSTANT IS 3600 N/m, SITS ON FRICTIONLESS ICE. HERE COMES ONE! THE BALL, m = 20 KG, HAS A VELOCITY OF 45 m/s. THE SPRING,



ARMED WITH A RAWLINGS® BASEBALL MITT, CATCHES THE BALL, IS MAXIMALLY COMPRESSED AND REMAINS COMPRESSED IN THIS POSITION. FIND: A) THE FINAL VELOCITY OF THE SUCCESSFUL CATCHER. (9 m/s) B) THE DISTANCE WHICH THE SPRING HAS BEEN COMPRESSED. (3 m)

10. INITIALLY, A SPRING HAS CONSTANT K = 300 N/m. WE CUT ONE-THIRD OF THE COILS OFF SAVING ONLY TWO-THIRDS. WE FIX ONE END TO THE WALL AND ATTACH A 50 KG MASS TO THE FREE END.



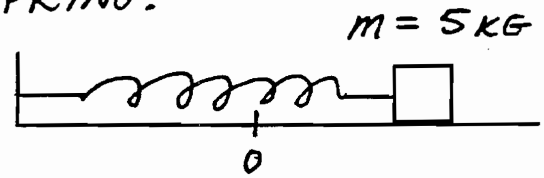

FIND: A) THE NEW SPRING CONSTANT B) THE WORK TO STRETCH IT FROM (3,0) TO (5,0) C) THE MAXIMUM SPEED IF WE RELEASE IT FROM REST AT (5,0). (450 N/m, 3600 J, 15 m/s)

# WORK, ENERGY AND CALCULUS

1. A TITANIUM SPRIÑG FOLLOWS HARVIE'S RATHER THAN HOOKE'S LAW. THE EQUATION FOR ITS FORCE IS: $F = -60X^3$.

A) FIND A FORMULA FOR THE POTENTIAL ENERGY OF THIS SPRING.

B)




FIND THE VALUE OF THE SPRING FORCE WHEN THE MASS IS LOCATED AT THE FOLLOWING POINTS:

(-3, 0), (-2, 0), (-1, 0), (0, 0), (1, 0), (2, 0), (3, 0).

C) FIND THE VALUE OF THE POTENTIAL ENERGY AT THOSE SAME SEVEN LOCATIONS.

D) FROM REST, WE USE OUR MUSCLES TO PULL THE BRICK FROM (1, 0) TO (3, 0), WHERE ITS FINAL SPEED IS ALSO ZERO. FIND THE WORK DONE BY OUR MUSCLES.

E) FROM REST AT (3, 0), WE RELEASE THE BRICK. FIND ITS SPEED AT THE FOLLOWING POINTS: (2, 0), (0, 0) AND (-2, 0).

2. A STERLING SPRING FOLLOWS DEBAKCSY'S LAW RATHER THAN HOOKE'S LAW. THE FORMULA FOR THE POTENTIAL ENERGY OF THIS SPRING IS: $PE = 210X^6$.

A) FIND A FORMULA FOR THE FORCE OF THIS SPRING.

B) CALCULATE THE P.E. OF THE SPRING AT $X = 2$.

C) CALCULATE THE SPRING FORCE AT $X = 2$.

3. FIND A FORMULA FOR THE P.E. FOR EACH OF THE FOLLOWING FORCES.

A) $F = -30X^4 - 42X^2$

B) $F = -24X$

C) $F = 7$

4. FIND A FORMULA FOR THE FORCE WHOSE POTENTIAL ENERGY IS GIVEN BELOW.

A) $PE = 18X^2$

B) $PE = 24X$

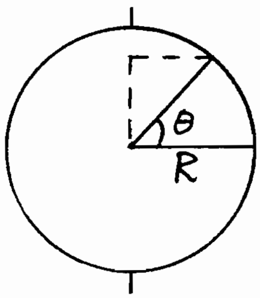
C) $PE = -6X^3 + 7X^2 - 4X + 5$

5. THE EARTH HAS MASS $5.98 \times 10^{24}$ KG AND RADIUS $6.378 \times 10^6$ m. THE UNIVERSAL GRAVITATION CONSTANT IS $6.67 \times 10^{-11}$ $Nm^2/KG^2$.

A) FIND THE ESCAPE VELOCITY FOR A PROJECTILE TO LEAVE THE GRAVITATIONAL FIELD OF EARTH.

B) FIND THE INITIAL KINETIC ENERGY OF A 1200 KG PROJECTILE WITH THIS VELOCITY.

6.




R = RADIUS OF THE EARTH

T = ROTATIONAL PERIOD OF THE EARTH'S SPIN.

θ = LATITUDE

A) IN TERMS OF R, T AND θ, FIND A FORMULA FOR THE ROTATIONAL SPEED OF THE EARTH AT A GIVEN LAUNCH SITE.

B) CAPE CANAVERAL'S LATITUDE IS 28.5° N.

$R = 6.378 \times 10^6$ m  $T = 86400$ SECONDS

FIND THE EARTH'S ROTATIONAL SPEED AT THE CAPE.

C) FIND THE PERCENT OF THE ROTATIONAL SPEED COMPARED TO THE ESCAPE VELOCITY.

ANSWERS: $PE = 15X^4$, 1620, 480, 60, 0, −60, −480, −1620, 1215, 240, 15, 0, 15, 240, 1215, 1200, −19.75, −22.04, −19.75; $F = -1260X^5$, 13440, −40320; $PE = 6X^5 + 14X^3$, $PE = 12X^2$, $PE = -7X$; $F = -36X$, $F = -24$, $F = 18X^2 - 14X + 4$; 11184, $7.5 \times 10^{10}$; $v = (2\pi R\cos\theta)/T$, 407.6, 3.64%