5 Energy and Machines

5-1 Work and Power

Vocabulary **Work:** The product of the component of the force exerted on an object in the direction of displacement and the magnitude of the displacement.

$$\textbf{work} = \textbf{(force)(displacement)} \quad \text{or} \quad W = F\Delta d$$

The SI unit for work is the **joule (J)**, which equals one **newton·meter (N·m).**

For maximum work to be done, the object *must* move in the direction of the force. If the object is moving at an angle to the force, determine the component of the force in the direction of motion. Remember, if the object does not move, or moves perpendicular to the direction of the force, no work has been done.

Vocabulary **Power:** The rate at which work is done.

$$\textbf{power} = \frac{\textbf{work}}{\textbf{elapsed time}} \quad \text{or} \quad P = \frac{W}{\Delta t}$$

The SI unit for power is the **watt (W)**, which equals one **joule per second (J/s).** One person is more powerful than another if he or she can do more work in a given amount of time, or can do the same amount of work in less time.

Solved Examples

Example 1: Bud, a very large man of mass 130 kg, stands on a pogo stick. How much work is done as Bud compresses the spring of the pogo stick 0.50 m?

Solution: First, find Bud's weight, which is the force with which he compresses the pogo stick spring.

Given: $m = 130$ kg
$g = 10.0$ m/s^2

Unknown: $w = ?$
Original equation: $w = mg$

Solve: $w = mg = (130 \text{ kg})(10.0 \text{ m/s}^2) = 1300 \text{ N}$

Now use this weight to solve for the work done to compress the spring.

Given: $F = 1300\text{ N}$
$\Delta d = 0.050\text{ m}$

Unknown: $W = ?$
Original equation: $W = F\Delta d$

Solve: $W = F\Delta d = (1300\text{ N})(0.050\text{ m}) = \mathbf{65\text{ J}}$

Don't get confused here by the two *W*'s you see in this example. The *w* in $w = mg$ means *weight* while the *W* in $W = F\Delta d$ means *work*. There are many ways to tell them apart, the most important of which is to understand how they are used in the context of the exercise. Also, the units used for each are quite different: weight is measured in newtons, and work is measured in joules. Last of all, weight is a vector and work is a scalar.

Example 2: After finishing her physics homework, Sherita pulls her 50.0-kg body out of the living room chair and climbs up the 5.0-m-high flight of stairs to her bedroom. How much work does Sherita do in ascending the stairs?

Solution: First find Sherita's weight. Her muscles exert a force to carry her weight up the stairs.

Given: $m = 50.0\text{ kg}$
$g = 10.0\text{ m/s}^2$

Unknown: $w = ?$
Original equation: $w = mg$

Solve: $w = mg = (50.0\text{kg})(10.0\text{ m/s}^2) = 500.\text{ N}$

Now use Sherita's weight (or force) to determine the amount of work done. It is important to note that when you are solving for the work done, you need know only the displacement of the body moved. The number of stairs climbed or their steepness is irrelevant. All that is important is the *change* in position.

Given: $F = 500.\text{ N}$
$\Delta d = 5.0\text{ m}$

Unknown: $W = ?$
Original equation: $W = F\Delta d$

Solve: $W = F\Delta d = (500.\text{ N})(5.0\text{ m}) = \mathbf{2500\text{ J}}$

Example 3: In the previous example, Sherita slowly ascends the stairs, taking 10.0 s to go from bottom to top. The next evening, in a rush to catch her favorite TV show, she runs up the stairs in 3.0 s. a) On which night does Sherita do more work? b) On which night does Sherita generate more power?

a) Sherita does the same amount of work on both nights because the force she exerts and her displacement are the same each time.

b) Sherita's power output varies because the time taken to do the same amount of work varies.

First night:

Given: $W = 2500\text{ J}$
$\Delta t = 10.0\text{ s}$

Unknown: $P = ?$
Original equation: $P = \dfrac{W}{\Delta t}$

Solve: $P = \frac{W}{\Delta t} = \frac{2500\text{ J}}{10.0\text{ s}} = \mathbf{250\ W}$

Second night:

Given: $W = 2500\text{ J}$
$\Delta t = 3.0\text{ s}$

Unknown: $P = ?$
Original equation: $P = \frac{W}{\Delta t}$

Solve: $P = \frac{W}{\Delta t} = \frac{2500\text{ J}}{3.0\text{ s}} = \mathbf{830\ W}$

Sherita generates more power on the second night.

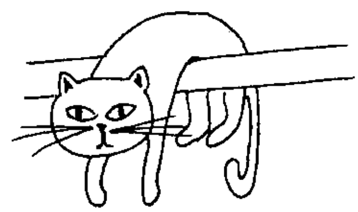
Practice Exercises

Exercise 1: On his way off to college, Russell drags his suitcase 15.0 m from the door of his house to the car at a constant speed with a horizontal force of 95.0 N. a) How much work does Russell do to overcome the force of friction? b) If the floor has just been waxed, does he have to do more work or less work to move the suitcase? Explain.

Answer: **a.** ____________________

Answer: **b.** ____________________

Exercise 2: Katie, a 30.0-kg child, climbs a tree to rescue her cat who is afraid to jump 8.0 m to the ground. How much work does Katie do in order to reach the cat?



Answer: ____________________

Exercise 3: Marissa does 3.2 J of work to lower the window shade in her bedroom a distance of 0.8 m. How much force must Marrisa exert on the window shade?

Answer: ____________________

Exercise 4: Atlas and Hercules, two carnival sideshow strong men, each lift 200.-kg barbells 2.00 m off the ground. Atlas lifts his barbells in 1.00 s and Hercules lifts his in 3.00 s. a) Which strong man does more work? b) Calculate which man is more powerful.

Answer: **a.** ____________________

Answer: **b.** ____________________

5-2 Energy

Potential and Kinetic Energy

Vocabulary **Energy:** The ability to do work.

There are many different types of energy. This chapter will focus on only mechanical energy, or the energy related to position (**potential energy**) and motion (**kinetic energy**).

Vocabulary **Potential Energy:** Energy of position, or stored energy.

An object gains gravitational potential energy when it is lifted from one level to a higher level. Therefore, we generally refer to the *change* in potential energy or ΔPE, which is proportional to the change in height, Δh.

Δ gravitational potential energy = (mass)(acceleration due to gravity)(Δ height)

or $\Delta PE = mg\Delta h$

It is important to remember that gravitational potential energy relies *only* upon the vertical change in height, Δh, and not upon the path taken.

In addition to gravitational potential energy, there are other forms of stored energy. For example, when a bow is pulled back and before it is released, the energy in the bow is equal to the work done to deform it. This stored or potential energy is written as $\Delta PE = F\Delta d$. Springs possess elastic potential energy when they are displaced from the equilibrium position. The equation for elastic potential energy will not be used in this chapter.

Vocabulary **Kinetic Energy:** Energy of motion.

The kinetic energy of an object varies with the square of the speed.

$$\textbf{kinetic energy} = \left(\frac{1}{2}\right)\textbf{(mass)(speed)}^2 \quad \text{or} \quad KE = \left(\frac{1}{2}\right)mv^2$$

The SI unit for energy is the **joule.** Notice that this is the same unit used for work. When work is done on an object, energy is transformed from one form to another. The sum of the changes in potential, kinetic, and heat energy is equal to the work done on the object. Mechanical energy is transformed into heat energy when work is done to overcome friction.

Conservation of Energy

According to the **law of conservation of energy,** energy cannot be created or destroyed. The total amount of mechanical energy in a system remains constant if no work is done by any force other than gravity.

In an isolated system where there are no mechanical energy losses due to friction

$$\Delta KE = \Delta PE$$

In other words, all the kinetic and potential energy before an interaction equals all the kinetic and potential energy after the interaction.

$$KE_o + PE_o = KE_f + PE_f \quad \text{or} \quad \left(\frac{1}{2}\right)mv_o^2 + mgh_o = \left(\frac{1}{2}\right)mv_f^2 + mgh_f$$

As a reminder, the terms with the subscript $_o$ are the initial conditions, while those with the subscript $_f$ are final conditions.

Solved Examples

Example 4: Legend has it that Isaac Newton "discovered" gravity when an apple fell from a tree and hit him on the head. If a 0.20-kg apple fell 7.0 m before hitting Newton, what was its change in PE during the fall?

Solution: For a given object, the change in PE depends only upon the change in position. The apple does not need to fall all the way to the ground to experience an energy change.

Given: $m = 0.20$ kg
$g = 10.0\ \text{m/s}^2$
$\Delta h = 7.0$ m

Unknown: $\Delta PE = ?$
Original equation: $\Delta PE = mg\Delta h$

Solve: $\Delta PE = mg\Delta h = (0.20\ \text{kg})(10.0\ \text{m/s}^2)(7.0\ \text{m}) = \mathbf{14\ J}$

Example 5: A greyhound at a race track can run at a speed of 16.0 m/s. What is the KE of a 20.0-kg greyhound as it crosses the finish line?

Given: $m = 20.0$ kg
$v = 16.0$ m/s

Unknown: KE = ?
Original equation: $KE = \left(\frac{1}{2}\right)mv^2$

Solve: $KE = \left(\frac{1}{2}\right)mv^2 = \left(\frac{1}{2}\right)(20.0\ \text{kg})(16.0\ \text{m/s})^2 = \mathbf{2560\ J}$

Example 6: In a wild shot, Bo flings a pool ball of mass m off a 0.68-m-high pool table, and the ball hits the floor with a speed of 6.0 m/s. How fast was the ball moving when it left the pool table? (Use the law of conservation of energy.)

Given: $v_f = 6.0$ m/s
$g = 10.0\ \text{m/s}^2$
$h_o = 0.68$ m
$h_f = 0$ m

Unknown: $v_o = ?$
Original equation: $\Delta KE = \Delta PE$

Solve: $KE_o + PE_o = KE_f + PE_f$ or $\left(\frac{1}{2}\right)mv_o^2 + mgh_o = \left(\frac{1}{2}\right)mv_f^2 + mgh_f$

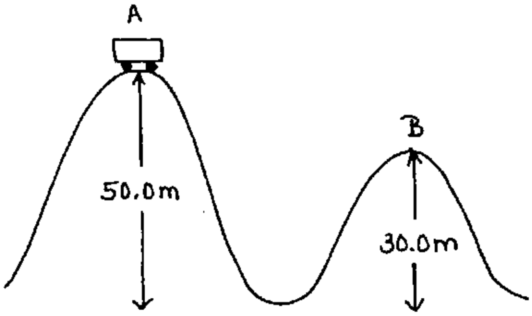
Notice that mass is contained in each of these equations. Therefore, it cancels out and does not need to be included in the calculation.

$$v_o = \sqrt{\frac{\left(\frac{1}{2}\right)mv_f^2 + mgh_f - mgh_o}{\left(\frac{1}{2}\right)m}} = \sqrt{\frac{\left(\frac{1}{2}\right)v_f^2 + gh_f - gh_o}{\frac{1}{2}}}$$

$$= \sqrt{\frac{\left(\frac{1}{2}\right)(6.0\ \text{m/s})^2 + (10.0\ \text{m/s}^2)(0\ \text{m}) - (10.0\ \text{m/s}^2)(0.68\ \text{m})}{\frac{1}{2}}}$$

$$= \sqrt{\frac{18\ \text{m}^2/\text{s}^2 - 6.8\ \text{m}^2/\text{s}^2}{\frac{1}{2}}} = \mathbf{4.7\ m/s}$$

Example 7: Frank, a San Francisco hot dog vender, has fallen asleep on the job. When an earthquake strikes, his 300-kg hot-dog cart rolls down Nob Hill and reaches point A at a speed of 8.00 m/s. How fast is the hot-dog cart going at point B when Frank finally wakes up and starts to run after it?



Solution: Because mass is contained in each of these equations, it cancels out and does not need to be included in the calculation. Also, the inclination of the hill makes no difference. All that matters is the change in height.

Given: $v_o = 8.00\ \text{m/s}$
$g = 10.0\ \text{m/s}^2$
$h_o = 50.0\ \text{m}$
$h_f = 30.0\ \text{m}$

Unknown: $v_f = ?$
Original equation: $\Delta KE = \Delta PE$

Solve: $KE_o + PE_o = KE_f + PE_f$ or $\left(\frac{1}{2}\right)mv_o^2 + mgh_o = \left(\frac{1}{2}\right)mv_f^2 + mgh_f$

$$v_f = \sqrt{\frac{\left(\frac{1}{2}\right)mv_o^2 + mgh_o - mgh_f}{\left(\frac{1}{2}\right)m}} = \sqrt{\frac{\left(\frac{1}{2}\right)v_o^2 + gh_o - gh_f}{\frac{1}{2}}}$$

$$= \sqrt{\frac{\left(\frac{1}{2}\right)(8.00\ \text{m/s})^2 + (10.0\ \text{m/s}^2)(50.0\ \text{m}) - (10.0\ \text{m/s}^2)(30.0\ \text{m})}{\frac{1}{2}}}$$

$$= \sqrt{\frac{32.0\ \text{m}^2/\text{s}^2 + 500.\ \text{m}^2/\text{s}^2 - 300.\ \text{m}^2/\text{s}^2}{\frac{1}{2}}}$$

$$= \sqrt{464\ \text{m}^2/\text{s}^2} = \mathbf{21.5\ m/s}$$

Practice Exercises

Exercise 5: It is said that Galileo dropped objects off the Leaning Tower of Pisa to determine whether heavy or light objects fall faster. If Galileo had dropped a 5.0-kg cannon ball to the ground from a height of 12 m, what would have been the change in PE of the cannon ball?

Answer: ____________________

Exercise 6: The 2000 Belmont Stakes winner, Commendable, ran the horse race at an average speed of 15.98 m/s. If Commendable and jockey Pat Day had a combined mass of 550.0 kg, what was their KE as they crossed the finish line?

Answer: ____________________

Exercise 7: Brittany is changing the tire of her car on a steep hill 20.0 m high. She trips and drops the 10.0-kg spare tire, which rolls down the hill with an initial speed of 2.00 m/s. What is the speed of the tire at the top of the next hill, which is 5.00 m high? (Ignore the effects of rotation KE and friction.)

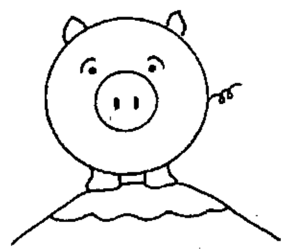
Answer: ____________________

Exercise 8: A Mexican jumping bean jumps with the aid of a small worm that lives inside the bean. a) If a bean of mass 2.0 g jumps 1.0 cm from your hand into the air, how much potential energy has it gained in reaching its highest point.
b) What is its speed as the bean lands back in the palm of your hand?

Answer: **a.** ____________________

Answer: **b.** ____________________

Exercise 9: A 500.-kg pig is standing at the top of a muddy hill on a rainy day. The hill is 100.0 m long with a vertical drop of 30.0 m. The pig slips and begins to slide down the hill. What is the pig's speed at the bottom of the hill? Use the law of conservation of energy.



Answer: ____________________

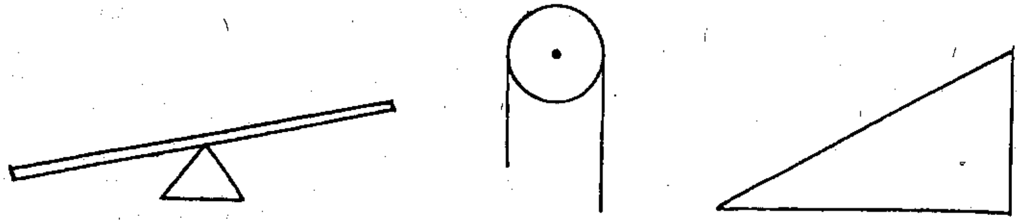
Exercise 10: While on the moon, the Apollo astronauts enjoyed the effects of a gravity much smaller than that on Earth. If Neil Armstrong jumped up on the moon with an initial speed of 1.51 m/s to a height of 0.700 m, what amount of gravitational acceleration did he experience?

Answer: ____________________

5-3 Machines and Efficiency

Vocabulary **Machine:** A device that helps do work by changing the magnitude or direction of the applied force.

Three common machines are the **lever, pulley,** and **incline.**



In an ideal situation, where frictional forces are negligible, work input equals work output.

$$F_{in}\Delta d_{in} = F_{out}\Delta d_{out}$$

However, situations are never ideal. The **actual mechanical advantage,** or **AMA,** of the machine is a ratio of the magnitude of the force out (resistance) to the magnitude of the force in (effort).

$$\textbf{actual mechanical advantage} = \frac{\textbf{force out (resistance)}}{\textbf{force in (effort)}} \quad \text{or} \quad \text{AMA} = \frac{F_{out}}{F_{in}}$$

On the other hand, the theoretical or **ideal mechanical advantage, IMA,** is based only on the geometry of the system and does not take frictional effects into account.

$$\textbf{ideal mechanical advantage} = \frac{\textbf{distance in (effort distance)}}{\textbf{distance out (resistance distance)}}$$

$$\text{or} \quad \text{IMA} = \frac{\Delta d_{in}}{\Delta d_{out}}$$

Because no machine is perfect and because you will always get out less work than you put in, you need to consider the efficiency of the machine that you are using. The more efficient the machine, the greater work output you will get for your work input. The efficiency will always be less than 100%.

Vocabulary **Efficiency:** The ratio of the work output to the work input.

$$\textbf{efficiency} = \frac{\textbf{work output}}{\textbf{work input}} = \frac{F_{out}\Delta d_{out}}{F_{in}\Delta d_{in}} = \frac{AMA}{IMA}$$

Efficiency has no units and is usually expressed as a percent.

Solved Examples

Example 8: A crate of bananas weighing 3000. N is shipped from South America to New York, where it is unloaded by a dock worker who lifts the crate by pulling with a force of 200. N on the rope of a pulley system. What is the actual mechanical advantage of the pulley system?

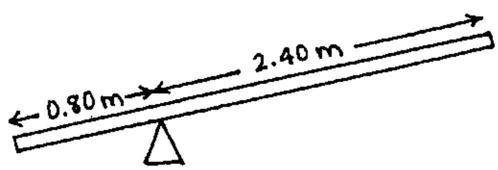
Given: $F_{out} = 3000.\ N$
$F_{in} = 200.\ N$

Unknown: AMA = ?
Original equation: $AMA = \frac{F_{out}}{F_{in}}$

Solve: $AMA = \frac{F_{out}}{F_{in}} = \frac{3000.\ N}{200.\ N} = \mathbf{15.0}$

The pulley exerts 15.0 times more force on the crate than the dock worker exerts to pull the rope. Notice that mechanical advantage has no units.

Example 9: Two clowns, of mass 50.0 kg and 70.0 kg respectively, are in a circus act performing a stunt with a trampoline and a seesaw. The smaller clown stands on the lower end of the seesaw while the larger clown jumps from the trampoline onto the raised side of the seesaw, propelling his friend into the air. a) what is the ideal mechanical advantage of the seesaw? b) If the larger clown exerts a force of 850. N on the seesaw as he jumps, how much force is exerted on the smaller clown?



a. The seesaw acts as a lever with the fulcrum 0.80 m from the left side. The ideal mechanical advantage is found by comparing the two distances.

Given: $\Delta d_{in} = 2.40\ m$
$\Delta d_{out} = 0.80\ m$

Unknown: IMA = ?
Original equation: $IMA = \frac{\Delta d_{in}}{\Delta d_{out}}$

Solve: $IMA = \frac{\Delta d_{in}}{\Delta d_{out}} = \frac{2.40\ m}{0.80\ m} = \mathbf{3.0}$

b. To answer this question, assume that the seesaw is 100% efficient and the work out equals the work in (which is highly unlikely!).

Given: $F_{in} = 850.\ \text{N}$
$\Delta d_{in} = 2.40\ \text{m}$
$\Delta d_{out} = 0.80\ \text{m}$

Unknown: $F_{out} = ?$
Original equation: $F_{in}\Delta d_{in} = F_{out}\Delta d_{out}$

Solve: $F_{out} = \dfrac{F_{in}\Delta d_{in}}{\Delta d_{out}} = \dfrac{(850.\ \text{N})(2.40\ \text{m})}{0.80\ \text{m}} = \mathbf{2550\ N}$

Example 10: A jackscrew with a handle 30.0 cm long is used to lift a car sitting on the jack. The car rises 2.0 cm for every full turn of the handle. What is the ideal mechanical advantage of the jack?

Solution: For a screw, $\text{IMA} = \dfrac{\Delta d_{in}}{\Delta d_{out}} = \dfrac{2\pi r}{\Delta h}$ where $2\pi r$ is the circumference of the circle through which the handle turns, and height, Δh, refers to the amount the jack (and hence the automobile) is raised.

Given: $r = 30.0\ \text{cm}$
$\Delta h = 2.0\ \text{cm}$

Unknown: $\text{IMA} = ?$
Original equation: $\text{IMA} = \dfrac{\Delta d_{in}}{\Delta d_{out}}$

Solve: $\text{IMA} = \dfrac{\Delta d_{in}}{\Delta d_{out}} = \dfrac{2\pi r}{\Delta h} = \dfrac{2\pi(30.0\ \text{cm})}{2.0\ \text{cm}} = \mathbf{94}$

Example 11: Jack and Jill went up the hill to fetch a pail of water. At the well, Jill used a force of 20.0 N to turn a crank handle of radius 0.400 m that rotated an axle of radius 0.100 m, so she could raise a 60.0-N bucket of water. a) What is the ideal mechanical advantage of the wheel? b) What is the actual mechanical advantage of the wheel? c) What is the efficiency of the wheel?

Solution: Since the crank handle and the axle both turn in a circle, $\Delta d_{in} = 2\pi r_c$ (where r_c is the radius of the crank handle) and $\Delta d_{out} = 2\pi r_a$ (where r_a is the radius of the axle).

a. *Given:* $r_c = 0.400\ \text{m}$
$r_a = 0.100\ \text{m}$

Unknown: $\text{IMA} = ?$
Original equation: $\text{IMA} = \dfrac{\Delta d_{in}}{\Delta d_{out}}$

Solve: $\text{IMA} = \dfrac{\Delta d_{in}}{\Delta d_{out}} = \dfrac{2\pi r_c}{2\pi r_a} = \dfrac{2\pi(0.400\ \text{m})}{2\pi(0.100\ \text{m})} = \mathbf{4.00}$

b. The force on the bucket of water is F_{out} and the force exerted by Jill is F_{in}.

Given: $F_{out} = 60.0\ \text{N}$
$F_{in} = 20.0\ \text{N}$

Unknown: $\text{AMA} = ?$
Original equation: $\text{AMA} = \dfrac{F_{out}}{F_{in}}$

Solve: $\text{AMA} = \dfrac{F_{out}}{F_{in}} = \dfrac{60.0\ \text{N}}{20.0\ \text{N}} = \mathbf{3.00}$

c. *Given:* AMA = 3.00
IMA = 4.00

Unknown: Eff = ?
Original equation: $\text{Eff} = \frac{\text{AMA}}{\text{IMA}}$

Solve: $\text{Eff} = \frac{\text{AMA}}{\text{IMA}} = \frac{3.00}{4.00} = 0.750 = \mathbf{75.0\%}$

Example 12: Clyde, a stubborn 3500-N mule, refuses to walk into the barn, so Farmer MacDonald must drag him up a 5.0-m ramp to his stall, which stands 0.50 m above ground level. a) What is the ideal mechanical advantage of the ramp? b) If Farmer MacDonald needs to exert a 450-N force on the mule to drag him up the ramp with a constant speed, what is the actual mechanical advantage of the ramp? c) What is the efficiency of the ramp?

Solution: For a ramp, ramp length is Δd_{in} and ramp height is Δd_{out}.

a. *Given:* $\Delta d_{in} = 5.0\text{ m}$
$\Delta d_{out} = 0.50\text{ m}$

Unknown: IMA = ?
Original equation: $\text{IMA} = \frac{\Delta d_{in}}{\Delta d_{out}}$

Solve: $\text{IMA} = \frac{\Delta d_{in}}{\Delta d_{out}} = \frac{5.0\text{ m}}{0.50\text{ m}} = \mathbf{10.}$

b. *Given:* $F_{out} = 3500\text{ N}$
$F_{in} = 450\text{ N}$

Unknown: AMA = ?
Original equation: $\text{AMA} = \frac{F_{out}}{F_{in}}$

Solve: $\text{AMA} = \frac{F_{out}}{F_{in}} = \frac{3500\text{ N}}{450\text{ N}} = \mathbf{7.8}$

c. *Given:* IMA = 10.
AMA = 7.8

Unknown: Eff = ?
Original equation: $\text{Eff} = \frac{\text{AMA}}{\text{IMA}}$

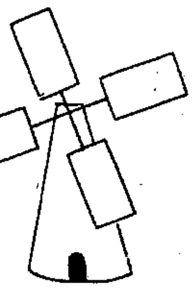
Solve: $\text{Eff} = \frac{\text{AMA}}{\text{IMA}} = \frac{7.8}{10.} = 0.78 = \mathbf{78\%}$

Practice Exercises

Exercise 11: Cathy, a 460-N actress playing Peter Pan, is hoisted above the stage in order to "fly" by a stagehand pulling with a force of 60. N on a rope wrapped around a pulley system. What is the actual mechanical advantage of the pulley system?

Answer: ____________________

Exercise 12: A windmill uses sails blown by the wind to turn an axle that allows a grindstone to grind corn into meal with a force of 90. N. The windmill has sails of radius 6.0 m blown by a wind that exerts a force of 15 N on the sails, and the axle of the grindstone has a radius of 0.50 m. a) What is the ideal mechanical advantage of the wheel? b) What is the actual mechanical advantage of the wheel? c) What is the efficiency of the wheel?

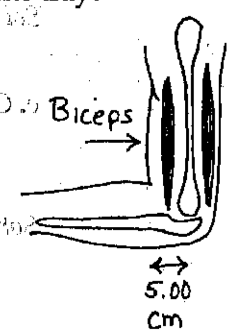


Answer: **a.** ____________________

Answer: **b.** ____________________

Answer: **c.** ____________________

Exercise 13: Winnie, a waitress, holds in one hand a 5.0-N tray stacked with twelve 3.5-N dishes. The length of her arm from her hand to her elbow is 30.0 cm and her biceps muscle exerts a force 5.0 cm from her elbow, which acts as a fulcrum. How much force must her biceps exert to allow her to hold the tray?



Answer: ____________________

Exercise 14: When building the pyramids, the ancient Egyptians were able to raise large stones to very great heights by using inclines. If an incline has an ideal mechanical advantage of 4.00 and the pyramid is 15.0 m tall, how much of an angle would the incline need in order for the Egyptian builder to reach the top?

Answer: ____________________

Exercise 15: The Ramseys are moving to a new town, so they have called in the ACME moving company to take care of their furniture. Debbie, one of the movers, slides the Ramseys' 2200-N china cabinet up a 6.0-m-long ramp to the moving van, which stands 1.0 m off the ground. a) What is the ideal mechanical advantage of the incline? b) If Debbie must exert a 500.-N force to move the china cabinet up the ramp with a constant speed, what is the actual mechanical advantage of the ramp? c) What is the efficiency of the ramp?

Answer: **a.** ____________________

Answer: **b.** ____________________

Answer: **c.** ____________________

Additional Exercises

A-1: On a ski weekend in Colorado, Bob, whose mass is 75.0 kg, skis down a hill that is inclined at an angle of 15.0° to the horizontal and has a vertical rise of 25.0 m. How much work is done by gravity on Bob as he goes down the hill?

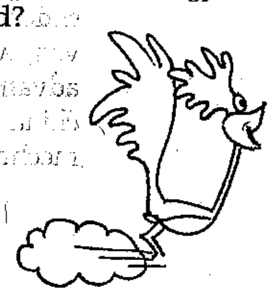
A-2: A pile driver is a device used to drive stakes into the ground. While building a fence, Adam drops a pile driver of mass 3000. kg through a vertical distance of 8.0 m. The pile driver is opposed by a resisting force of 5.0×10^6 N. How far is the stake driven into the ground on the first stroke?

A-3: At Six Flags New England in Agawam, Massachusetts, a ride called the Cyclone is a giant roller coaster that ascends a 34.1-m hill and then drops 21.9 m before ascending the next hill. The train of cars has a mass of 4727 kg. a) How much work is required to get an empty train of cars from the ground to the top of the first hill? b) What power must be generated to bring the train to the top of the first hill in 30.0 s? c) How much PE is converted into KE from the top of the first hill to the bottom of the 21.9-m drop?

A-4: A flea gains 1.0×10^{-7} J of PE jumping up to a height of 0.030 m from a dog's back. What is the mass of the flea?

A-5: At target practice, Diana holds her bow and pulls the arrow back a distance of 0.30 m by exerting an average force of 40.0 N. What is the potential energy stored in the bow the moment before the arrow is released?

A-6: The coyote, whose mass is 20.0 kg, is chasing the roadrunner when the coyote accidentally runs off the edge of a cliff and plummets to the ground 30.0 m below. What force does the ground exert on the coyote as he makes a coyote-shaped dent 0.420 m deep in the ground?



A-7: A 0.080-kg robin, perched on a power line 6.0 m above the ground, swoops down to snatch a worm from the ground and then returns to an 8.0-m-high tree branch with his catch. a) By how much did the bird's PE increase in its trip from the power line to the tree branch? b) How would your answer have changed if the bird had flown around a bit before landing on the tree branch?

A-8: Blackie, a cat whose mass is 5.45 kg, is napping on top of the refrigerator when he rolls over and falls. Blackie has a KE of 85.5 J just before he lands on his feet on the floor. How tall is the refrigerator?

A-9: Calories measure energy we get from food, and one dietary Calorie is equal to 4187 J. The average food energy intake for human beings is 2000. Calories/day. Assume you have a mass of 55.0 kg and you want to burn off all the Calories you consume in one day. How high a mountain would you have to climb to do so? (Note: This calculation ignores the large amount of energy the body continually loses to heat.)

A-10: From a height of 2.15 m above the floor of Boston's Fleet Center, forward Paul Pierce tosses a shot straight up next to the basketball hoop with a KE of 5.40 J. If his regulation-size basketball has a mass of 0.600 kg, will his shot go as high as the 3.04-m hoop? Use the law of conservation of energy.

A-11: Mr. Macintosh, a computer technician, uses a screwdriver with a handle of radius 1.2 cm to remove a screw in the back of a computer. The screw moves out 0.20 cm on each complete turn. What is the ideal mechanical advantage of the screwdriver?

A-12: Tom's favorite pastime is fishing. a) How much work is required for Tom to reel in a 10.0-kg bluefish from the water's surface to the deck of a fishing boat, 5.20 m above the water, if the reel of his fishing pole is 85.0% efficient? b) If Tom applies a force of 15 N to the reel's crank handle, what is the actual mechanical advantage of the fishing pole? c) What is the ideal mechanical advantage of the fishing pole?

A-13: A nutcracker 16 cm long is used to crack open a Brazil nut that is placed 12 cm from where your hand is squeezing the nutcracker. What is the ideal mechanical advantage of the nutcracker?

Challenge Exercises for Further Study

B-1: A 5.00-N salmon swims 20.0 m upstream against a current that provides a resistance of 1.50 N. This portion of the stream rises at an angle of 10.0° with respect to the horizontal. a) How much work is done by the salmon against the current? b) What is the gain in PE by the salmon? c) What is the total work that must be done by the salmon? d) If the salmon takes 40.0 s to swim the distance, what power does it exert in doing so?

B-2: A 30-kg shopping cart full of groceries sitting at the top of a 2.0-m hill begins to roll until it hits a stump at the bottom of the hill. Upon impact, a 0.25-kg can of peaches flies horizontally out of the shopping cart and hits a parked car with an average force of 490 N. How deep a dent is made in the car?

B-3: Using her snowmobile, Midge pulls a 60.0-kg skier up a ski slope inclined at an angle of 12.0° to the horizontal. The snowmobile exerts a force of 200. N parallel to the hill. If the coefficient of friction between the skis and the snow is 0.120, how fast is the skier moving after he has been pulled for 100.0 m starting from rest? (Ignore the effects of the static friction that must be overcome to initially start him in motion.) Use the law of conservation of energy.

B-4: Jose, whose mass is 45.0 kg, is riding his 5.0-kg skateboard down the sidewalk with a constant speed of 6.0 m/s when he rolls across a 10.0-m-long patch of sand on the pavement. The sand provides a force of friction of 6.0 N. What is Jose's speed as he emerges from the sandy section?

B-5: Eben lifts an engine out of his Volkswagen with the help of a winch that allows him to raise the engine 0.020 m for every 0.90 m he pulls on the cable. Eben expends 1000. J of energy to lift the 800.-N engine 0.50 m. a) What is the efficiency of the winch? b) What is the ideal mechanical advantage of the winch? c) What is the actual mechanical advantage of the winch? d) What force does Eben exert to lift the engine?