HUMBER ENGINEERING

ENGI 1000 - Physics 1

WEEK 9 - MODULE 6

HUMBER

WE ARE HUMBER

Module 6
Energy of a System – Part 2

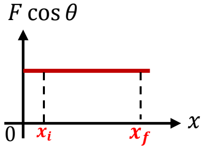
- Conservative versus Nonconservative Forces
- Work Done by Nonconservative Forces
- Conservation of Mechanical Energy
- Power
- Isolated and Non-isolated Systems

What we Already Know?

- **Work** is the measure of energy transfer when a force moves an object through a displacement.

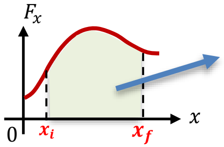
Work done by a constant force

$$W = (F\cos\theta)\Delta x$$



Work done by a variable force

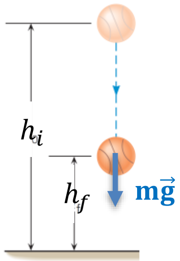
$$W = \int_{x_i}^{x_f} F_x\,dx$$



The work done by the force is the area under the curve.

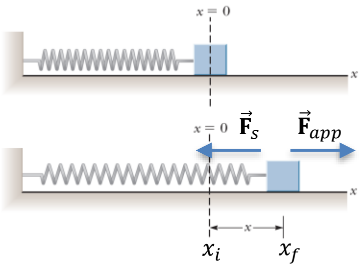
Work done by the gravitational force

$$W_{gravity} = mg(h_i - h_f)$$



Work done by the spring on the object

$$W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$$



Work done by an external force on the spring

$$W_{ext} = \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2$$

SAULT COLLEGE
HUMBER
Faculty of Applied Sciences & Technology

What we Already Know?

- **Energy** is simply defined as the ability of an object to do work.
  - Kinetic Energy → The energy of a moving object has because of its motion. ➡ $K \equiv \frac{1}{2}mv^2$
  - Potential Energy → The energy stored in an object, which gives the object the potential to do work later.

Gravitational potential energy ➡ $\boxed{U_g \equiv mgh}$

$$W_g = mg(h_i - h_f) = mgh_i - mgh_f = U_i - U_f = \Delta U_g$$

Elastic potential energy ➡ $\boxed{U_s \equiv \frac{1}{2}kx^2}$

$$W_{ext} = \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2 = U_f - U_i = \Delta U_s$$

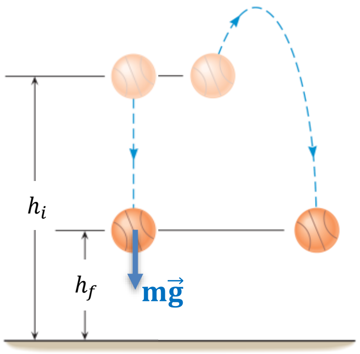
- The **Work-Energy Theorem** states that the work applied to a system is equal to the change in kinetic energy of that system.

$$\boxed{W_{ext} = \Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2}$$

Conservative vs. Nonconservative Forces

- Recall the work done by the gravitational force

$$\boxed{W_g = mg(h_i - h_f)}$$



- It depends only on the <u>initial</u> and <u>final heights</u>, and not on the <u>path</u> between these heights.
- The gravitational force is called a conservative force.

Definition of Conservative Force: Version 1

- A force is conservative when the work it does on a moving object is independent of the path between the object's initial and final positions.

- Another example of conservative force:
  - Elastic force of a spring

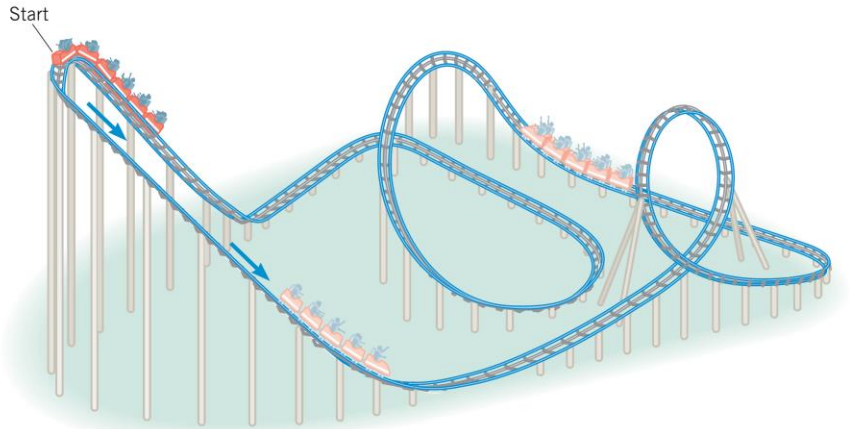
$$\boxed{W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2}$$

Conservative vs. Nonconservative Forces

Definition of Conservative Force: Version 2

- A force is conservative when it does no net work on an object moving around a *closed path*, starting and finishing at the same point.

- The path that begins and ends at the same place, is called a *closed path*.
- In the roller coaster car racing path, assuming no friction or air resistance, the gravitational force is the only force that does work.



- On the downward parts $\rightarrow$ $W_g > 0$, K increased
- On the upward parts $\rightarrow$ $W_g < 0$, K decreased
- Over the entire trip the net work is zero for the closed path and the car returns to the starting point with the same kinetic energy.

Conservative vs. Nonconservative Forces

Definition of Nonconservative Force

- A force is nonconservative if the work it does on an object depends on the path of the motion, and the total work done by the nonconservative force on a *closed path* is not zero.

- Examples of nonconservative forces are:
  - Friction Force
  - Air Resistance Force
  - Tension Force
  - Normal Force

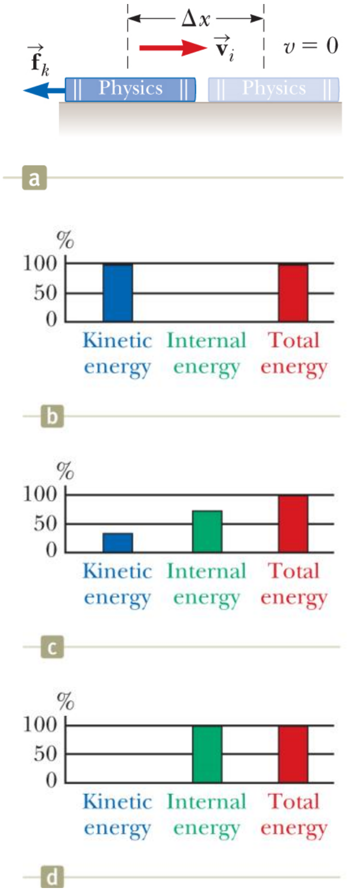
- The work done by nonconservative forces results in change in the internal energy of the system.

What is internal energy?

Internal Energy

- If an object slides on a surface, the surface in contact can become warmer.
- Structural changes in an object can occur when an external force is applied.
- The energy associated with both temperature and structure is called **internal energy (E_{int})** of the object.

- Imagine book in figure (a) has been accelerated by your hand and is now sliding to the right on surface of table and slowing down due to friction force.
  - Figure (b): system contains kinetic energy at instant the book released by your hand
  - Figure (c): kinetic energy transforming to internal energy as book slows down due to friction force
  - Figure (d): after book has stopped sliding kinetic energy = 0
    - System now contains only internal energy E_{int}



Quick Quiz 1

- A car starts with speed v_i, but the driver puts on the brakes and the car slows to a stop. As the car is slowing down, its kinetic energy is transformed to

  a) Stopping energy
  b) Gravitational potential energy
  c) Energy of motion
  d) Internal thermal energy
  e) Energy of rest

Quick Quiz 2

- Two children stand on a platform at the top of a curving slide next to a backyard swimming pool. At the same moment the smaller child hops off to jump straight down into the pool, the bigger child releases herself at the top of the frictionless slide.

Upon reaching the water, the **kinetic energy** of the smaller child compared with that of the larger child is:

a) greater
b) less
c) equal

Upon reaching the water, the **speed** of the smaller child compared with that of the larger child is:

a) greater
b) less
c) equal

Work Done by Nonconservative Forces

- In normal situations, conservative forces and nonconservative forces act simultaneously on an object.

$$W_{ext} = W_c + W_{nc}$$

Work done by the net external force

Work done by the conservative forces

Work done by the nonconservative forces

- From the work-energy theorem we have

$$\boxed{W_{ext} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2} \Rightarrow W_c + W_{nc} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

- If the only conservative force acting is the gravitational force, then

$$mg(h_i - h_f) + W_{nc} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

$$W_{nc} = \underbrace{\left(\tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2\right)}_{\text{Change in kinetic energy}} + \underbrace{(mgh_f - mgh_i)}_{\text{Change in gravitational potential energy}}$$

$$\Rightarrow \boxed{W_{nc} = \Delta K + \Delta U_g}$$

Work done by nonconservative forces

The Conservation of Mechanical Energy

- Total mechanical energy (E_{mech}) is defined as the sum of the kinetic energy and potential energy of the object.

$$\boxed{E_{mech} \equiv K + U}$$

The Principle of Conservation of Mechanical Energy

- If the net work done by the nonconservative forces is zero $W_{nc} = 0J$, the total mechanical energy remains constant along the path between the initial and final points.

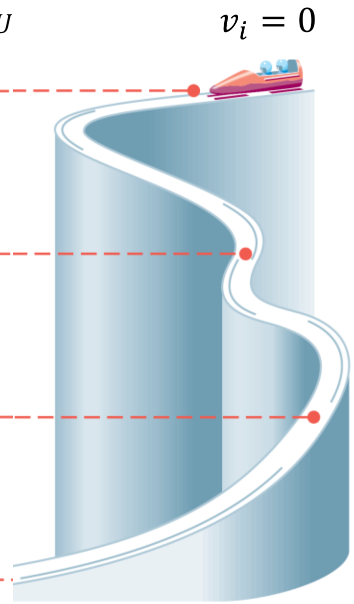
The principle of conservation of mechanical energy

$$\boxed{E_{mf} = E_{mi}}$$

The Conservation of Mechanical Energy

- For example, assume the transformation of energy for a bobsled run.
- If nonconservative forces, such as friction and wind resistance, are ignored.
- The normal force, being directed perpendicular to the path does no work.
- Only the gravitational force does work.
- The total mechanical energy E_{mech} remains constant at all points along the run.
- It is <u>all potential energy at the top</u> and <u>all kinetic energy at the bottom.</u>

K	U	$E_{mech} = K + U$
0 J	600 000 J	600 000 J
200 000 J	400 000 J	600 000 J
400 000 J	200 000 J	600 000 J
600 000 J	0 J	600 000 J

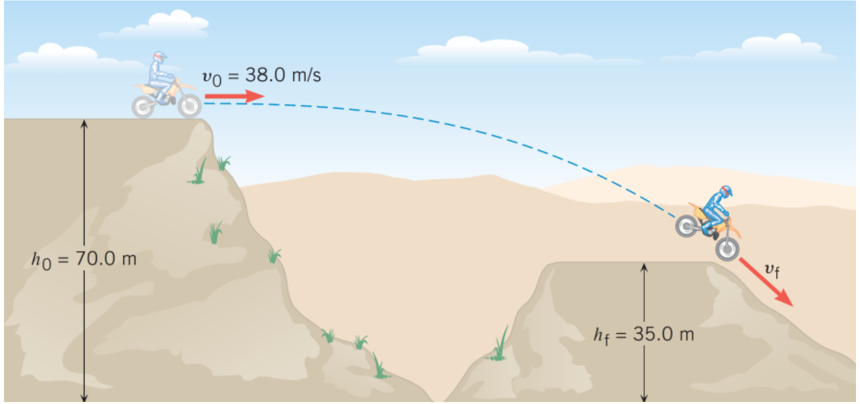


The Conservation of Mechanical Energy

Example 1 (Daredevil Motorcyclist): A motorcyclist is trying to leap across the canyon by driving horizontally off the cliff at a speed of 38.0 m/s. Ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.

Since air resistance is being ignored once the cycle leaves the cliff, no forces other than gravity act on the cycle. Thus, the work done by external nonconservative forces is zero. $W_{nc} = 0\ J$.

The principle of conservation of mechanical energy:



$$\boxed{E_{mf} = E_{mi}} \quad \rightarrow \quad K_f + U_f = K_i + U_i$$

$$\frac{1}{2}mv_f^2 + mgh_f = \frac{1}{2}mv_i^2 + mgh_i$$

$$v_f = \sqrt{v_i^2 + 2g(h_i - h_f)}$$

$$v_f = \sqrt{(38.0\ m/s)^2 + 2(9.8\ m/s^2)(70.0\ m - 35.0\ m)} = 46.2\ m/s$$

The Conservation of Mechanical Energy

Example 2 (A Giant Roller Coaster): A giant roller coaster ride includes a vertical drop of 127 m. Suppose that the coaster has a speed of 6.0 m/s at the top of the drop.

Neglect friction and air resistance and find the speed of the riders at the bottom.

Since we are neglecting friction and air resistance, we may set the work done by these forces equal to zero.

A normal force from the seat acts on each rider, but this force is perpendicular to the motion, so it does not do any work.

Thus, the work done by external nonconservative forces is zero. $W_{nc} = 0\ J$

We may use the principle of conservation of mechanical energy to find the speed of the riders at the bottom.

The Conservation of Mechanical Energy

Example 2 (A Giant Roller Coaster): A giant roller coaster ride includes a vertical drop of 127 m. Suppose that the coaster has a speed of 6.0 m/s at the top of the drop.

Neglect friction and air resistance and find the speed of the riders at the bottom.

The principle of conservation of mechanical energy:

$$\boxed{E_{mf} = E_{mi}} \quad \rightarrow \quad K_f + U_f = K_i + U_i$$

$$\frac{1}{2}mv_f^2 + mgh_f = \frac{1}{2}mv_i^2 + mgh_i$$

$$v_f = \sqrt{v_i^2 + 2g(h_i - h_f)}$$

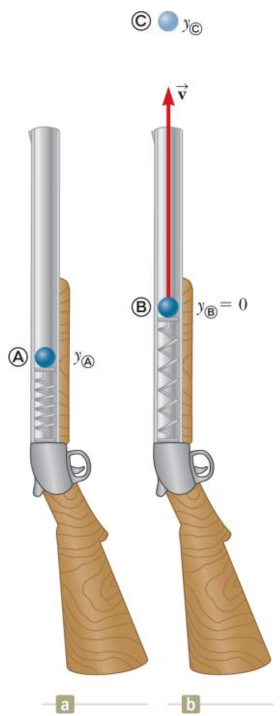
$$v_f = \sqrt{(6.0\ m/s)^2 + 2(9.8\ m/s^2)(127\ m)} = 50.3\ m/s$$

SAULT COLLEGE HUMBER Faculty of Applied Sciences & Technology

The Conservation of Mechanical Energy

Example 3 (Spring-Loaded Popgun): The launching mechanism of a popgun consists of a trigger-released spring. The spring is compressed to a position y_A, and the trigger is fired.

The projectile of mass m rises to a position y_C above the position at which it leaves the spring, indicated in the figure as position $y_B = 0$. Consider a firing of the gun for which m = 35.0 g, y_A = –0.120 m, and y_C = 20.0 m.



(a) Neglecting all resistive forces, determine the spring constant.

The principle of conservation of mechanical energy from point A to C:

$$\boxed{E_{mf} = E_{mi}} \rightarrow \underbrace{K_f + U_f}_{\text{At point C}} = \underbrace{K_i + U_i}_{\text{At point A}} \rightarrow 0 + (mgy_C + 0) = 0 + \left(mgy_A + \frac{1}{2}kx^2\right)$$

$$k = \frac{2mg(y_C - y_A)}{x^2} = \frac{2(0.0350\ \text{kg})(9.80\ \text{m/s}^2)[20.0\ \text{m} - (-0.120\ \text{m})]}{(0.120\ \text{m})^2}$$

$$= \boxed{958\ \text{N/m}}$$

The Conservation of Mechanical Energy

Example 3 (Spring-Loaded Popgun): The launching mechanism of a popgun consists of a trigger-released spring. The spring is compressed to a position y_A, and the trigger is fired.

The projectile of mass m rises to a position y_C above the position at which it leaves the spring, indicated in the figure as position $y_B = 0$. Consider a firing of the gun for which $m = 35.0$ g, $y_A = -0.120$ m, and $y_C = 20.0$ m.

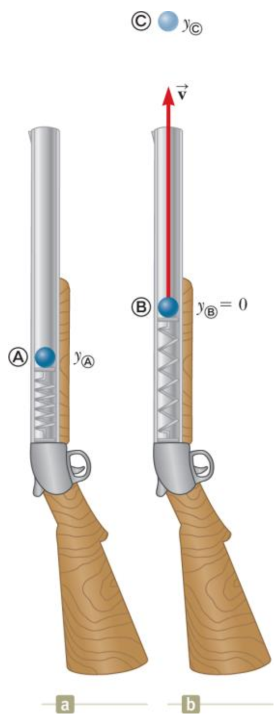
(b) Find the speed of the projectile as it moves through the equilibrium position B of the spring.

The principle of conservation of mechanical energy from point A to B:

$$\boxed{E_{mf} = E_{mi}} \rightarrow \underbrace{K_f + U_f}_{\text{At point B}} = \underbrace{K_i + U_i}_{\text{At point A}} \rightarrow \frac{1}{2}mv_B^2 + (0+0) = 0 + \left(mgy_A + \frac{1}{2}kx^2\right)$$

$$v_\mathrm{B} = \sqrt{\frac{kx^2}{m} + 2gy_\mathrm{A}} = \sqrt{\frac{(958\ \mathrm{N/m})(0.120\ \mathrm{m})^2}{(0.0350\ \mathrm{kg})} + 2(9.80\ \mathrm{m/s^2})(-0.120\ \mathrm{m})}$$

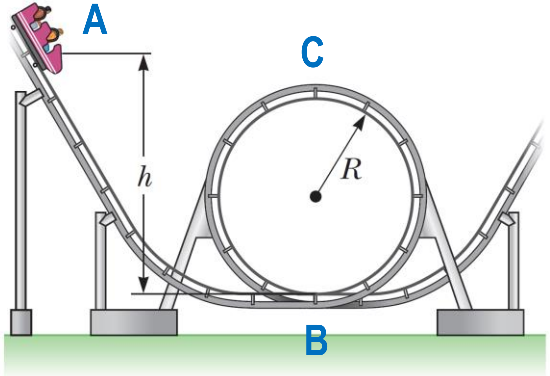
$$= \boxed{19.8\ \mathrm{m/s}}$$



The Conservation of Mechanical Energy

Example 4 (A Roller Coaster Car): A roller-coaster car is released from rest from a height *h* and then moves freely with negligible friction. The roller-coaster track includes a circular loop of radius *R* in a vertical plane.

Suppose the car barely makes it around the loop; at the top of the loop, the riders are upside down and feel weightless. Find the required height *h* of the release point above the bottom of the loop in terms of *R*.



The principle of conservation of mechanical energy from point A to B:

$$\boxed{E_{mf} = E_{mi}} \rightarrow \underbrace{K_f + U_f}_{\text{At point B}} = \underbrace{K_i + U_i}_{\text{At point A}}$$

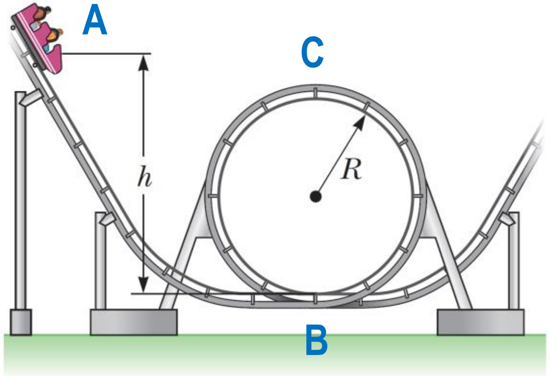
$$\frac{1}{2}mv_B^2 + 0 = 0 + mgh \rightarrow h = \frac{v_B^2}{2g}$$

At this step we have to find the v_B in terms of R

The Conservation of Mechanical Energy

Example 4 (A Roller Coaster Car): A roller-coaster car is released from rest from a height *h* and then moves freely with negligible friction. The roller-coaster track includes a circular loop of radius *R* in a vertical plane.

Suppose the car barely makes it around the loop; at the top of the loop, the riders are upside down and feel weightless. Find the required height *h* of the release point above the bottom of the loop in terms of *R*.



The principle of conservation of mechanical energy from point B to C:

$$\boxed{E_{mf} = E_{mi}} \rightarrow \underbrace{K_f + U_f}_{\text{At point C}} = \underbrace{K_i + U_i}_{\text{At point B}}$$

$$\frac{1}{2}mv_C^2 + mg(2R) = \frac{1}{2}mv_B^2 + 0 \rightarrow v_C^2 + 4gR = v_B^2 \rightarrow 5gR = v_B^2$$

Apply the Newton's second law at point C:

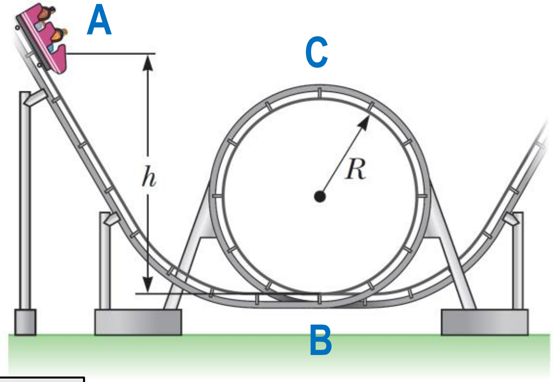
$$\sum F_c = ma_c \rightarrow n_c + mg = m\frac{v_c^2}{R} \rightarrow mg = m\frac{v_c^2}{R} \rightarrow v_c = \sqrt{gR}$$

SAULT COLLEGE
HUMBER Faculty of Applied Sciences & Technology

The Conservation of Mechanical Energy

Example 4 (A Roller Coaster Car): A roller-coaster car is released from rest from a height *h* and then moves freely with negligible friction. The roller-coaster track includes a circular loop of radius *R* in a vertical plane.

Suppose the car barely makes it around the loop; at the top of the loop, the riders are upside down and feel weightless. Find the required height *h* of the release point above the bottom of the loop in terms of *R*.



The principle of conservation of mechanical energy from point A to B:

$$\boxed{E_{mf} = E_{mi}} \rightarrow \underbrace{K_f + U_f}_{\text{At point B}} = \underbrace{K_i + U_i}_{\text{At point A}}$$

$$\frac{1}{2}mv_B^2 + 0 = 0 + mgh \rightarrow h = \frac{v_B^2}{2g} = \frac{5gR}{2g} \rightarrow \boxed{h = \frac{5}{2}R}$$

The minimum initial height required for the car to complete the loop.

Nonconservative Forces and Mechanical Energy

- Most moving objects experience nonconservative forces, such as friction and air resistance. Then the work done by the net nonconservative forces is not zero.

- We can rewrite the net work done by the nonconservative forces in terms of total mechanical energy:

$$\boxed{W_{nc} = \Delta K + \Delta U} \Rightarrow W_{nc} = (K_f - K_i) + (U_f - U_i)$$

$$W_{nc} = \underbrace{(K_f + U_f)}_{\text{Final mechanical energy}} - \underbrace{(K_i + U_i)}_{\text{Initial mechanical energy}} \Rightarrow \boxed{W_{nc} = E_{mf} - E_{mi}}$$

Work done by nonconservative forces

- The sum of the initial energies of a system plus the work done on the system by external forces equals the sum of the final energies of the system.

$$\boxed{E_{mi} + W_{nc} = E_{mf}}$$

SAULT COLLEGE HUMBER Faculty of Applied Sciences & Technology

Nonconservative Forces and Mechanical Energy

Example 5 (A Giant Roller Coaster): A giant roller coaster ride includes a vertical drop of 127 m. Suppose that the coaster has a speed of 6.0 m/s at the top of the drop.

In Example 2, we ignored nonconservative forces, such as friction. In reality, however, such forces are present when the roller coaster descends. The actual speed of the riders at the bottom is 45.0 m/s, which is less than that determined in Example 2.

Find the work done by nonconservative forces on a 55.0 kg rider during the vertical drop.

Since the speed at the top, the final speed, and the vertical drop are given, we can determine the initial and final total mechanical energies of the rider.

Nonconservative Forces and Mechanical Energy

Example 5 (A Giant Roller Coaster): A giant roller coaster ride includes a vertical drop of 127 m. Suppose that the coaster has a speed of 6.0 m/s at the top of the drop.

Work done by nonconservative forces:

$$\boxed{W_{nc} = E_{mf} - E_{mi}} \quad \rightarrow \quad W_{nc} = (K_f + U_f) - (K_i + U_i)$$

$$W_{nc} = \left(\frac{1}{2}mv_f^2 + mgh_f\right) - \left(\frac{1}{2}mv_i^2 + mgh_i\right)$$

$$W_{nc} = \frac{1}{2}m\left(v_f^2 - v_i^2\right) - mg(h_i - h_f)$$

$$W_{nc} = \frac{1}{2}(55.0\,kg)[(45.0\,m/s)^2 - (6.0\,m/s)^2] - (55.0\,kg)(9.8\,m/s^2)(127\,m)$$

$$= -1.4 \times 10^4\,J$$

Nonconservative Forces and Mechanical Energy

Example 6 (Fireworks): A 0.20 kg rocket in a fireworks display is launched from rest and follows an erratic flight path to reach the point *P*, which is 29 m above the starting point. In the process, 425 J of work is done on the rocket by the nonconservative force generated by the burning propellant. Ignoring air resistance and the mass lost due to the burning propellant, find the speed v_f of the rocket at the point *P*.

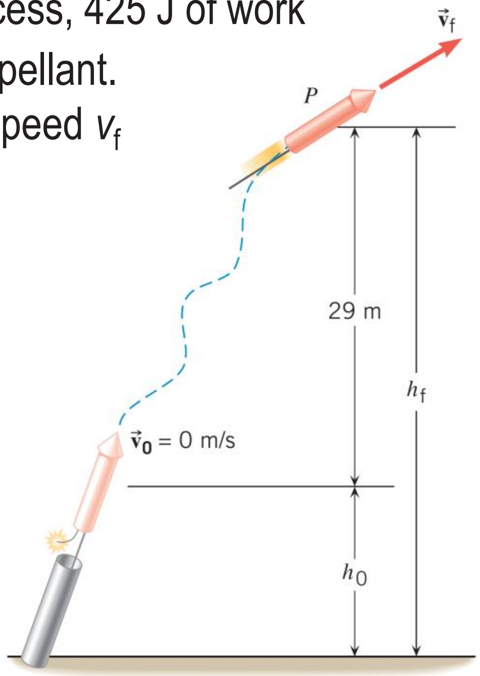
The only nonconservative force acting on the rocket is the force generated by the burning propellant

$$\boxed{W_{nc} = E_{mf} - E_{mi}}$$

$$W_{nc} = (K_f + U_f) - (K_i + U_i) \quad \rightarrow \quad W_{nc} = \left(\frac{1}{2}mv_f^2 + mgh_f\right) - \left(\frac{1}{2}mv_i^2 + mgh_i\right)$$

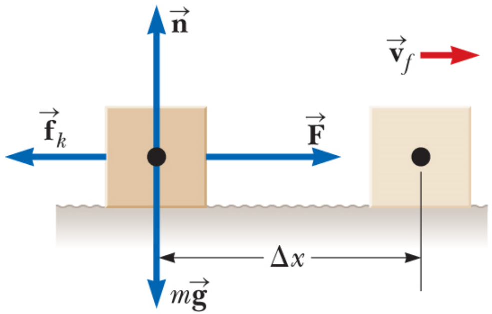
$$v_f = \sqrt{\frac{2\left[W_{nc} + \frac{1}{2}mv_i^2 - mg(h_f - h_i)\right]}{m}}$$

$$v_f = \sqrt{\frac{2[425\, J + 0 \; - (0.20\, kg)(9.8\, m)(29\, m)]}{0.20\, kg}} = 61\, m/s$$



Nonconservative Forces and Mechanical Energy

Example 7 (A Block Pulled on a Rough Surface): A 6.0-kg block initially at rest is pulled to the right along a horizontal surface by a constant horizontal force of magnitude 12 N.



Find the speed of the block after it has moved 3.0 m if the surfaces in contact have a coefficient of kinetic friction of 0.15.

Work done by nonconservative forces:

$$\boxed{W_{nc} = E_{mf} - E_{mi}}$$

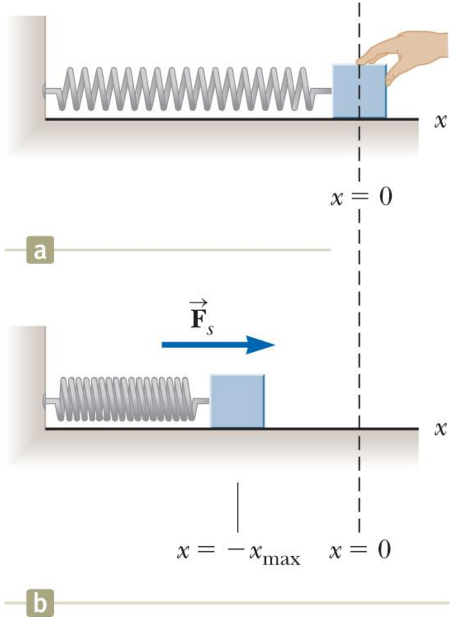
$$W_{nc} = (K_f + U_f) - (K_i + U_i) \quad \rightarrow \quad F cos\theta\, \Delta x + f_k \cos\theta\, \Delta x = \left(\frac{1}{2} m v_f^2 + 0\right) - (0 + 0) \quad \rightarrow \quad F\Delta x - f_k \Delta x = \frac{1}{2} m v_f^2$$

$$v_f = \sqrt{\frac{2}{m}(F\Delta x - f_k \Delta x)} = \sqrt{2\Delta x\left(\frac{F}{m} - \mu_k g\right)} = \sqrt{2(3.0\ \text{m})\left[\frac{12\ \text{N}}{6.0\ \text{kg}} - (0.15)(9.80\ \text{m/s}^2)\right]} = \boxed{1.8\ \text{m/s}}$$

Nonconservative Forces and Mechanical Energy

Example 8 (A Block-Spring System): A block of mass 1.6 kg is attached to a horizontal spring that has a force constant of 1000 N/m. The spring is compressed 2.0 cm and is then released from rest.

(a) Calculate the speed of the block as it passes through the equilibrium position $x = 0$ if the surface is frictionless.



The principle of conservation of mechanical energy:

$$\boxed{E_{mf} = E_{mi}} \quad \rightarrow \quad K_f + U_f = K_i + U_i$$

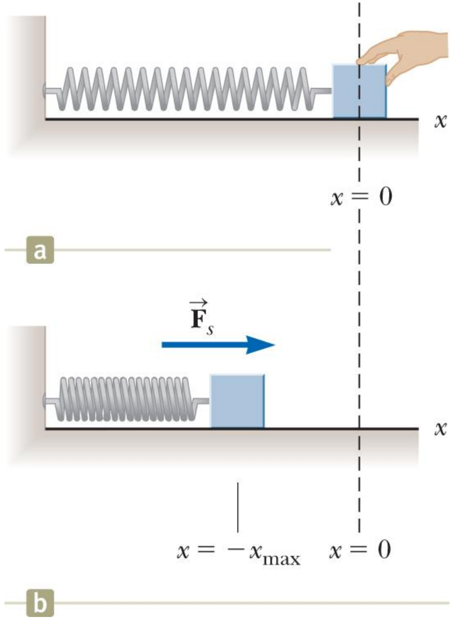
$$\frac{1}{2}mv_f^2 + 0 = 0 + \frac{1}{2}kx^2 \quad \rightarrow \quad v_f = x\sqrt{\frac{k}{m}}$$

$$v_f = (0.020\ \mathrm{m})\sqrt{\frac{1000\ \mathrm{N/m}}{1.6\ \mathrm{kg}}} = \boxed{0.50\ \mathrm{m/s}}$$

Nonconservative Forces and Mechanical Energy

Example 8 (A Block-Spring System): A block of mass 1.6 kg is attached to a horizontal spring that has a force constant of 1000 N/m. The spring is compressed 2.0 cm and is then released from rest.

(b) Calculate the speed of the block as it passes through the equilibrium position $x = 0$ if a constant friction force of 4.0 N retards its motion from the moment it is released.



Work done by nonconservative forces: $\boxed{W_{nc} = E_{mf} - E_{mi}}$

$$W_{nc} = (K_f + U_f) - (K_i + U_i) \quad \rightarrow \quad f_k \cos\theta \, \Delta x = \left(\frac{1}{2} m v_f^2 + 0\right) - \left(0 + \frac{1}{2} k x^2\right)$$

$$v_f = \sqrt{\frac{2}{m}\left(\frac{1}{2} k x^2 - f_k \Delta x\right)}$$

$$v_f = \sqrt{\frac{2}{1.6\ \mathrm{kg}}\left[\frac{1}{2}(1000\ \mathrm{N/m})(0.20\ \mathrm{m})^2 - (4.0\ \mathrm{N})(0.020\ \mathrm{m})\right]} = 0.39\ \mathrm{m/s}$$

Power

- In many situations, the time it takes to do work is just as important as the amount of work that is done.
- The time rate of energy transfer is called the **instantaneous power *P*** and is defined as

$$\boxed{P \equiv \frac{dE}{dt}}$$

- We also define the work as the energy transfer. Therefore, If an external force is applied to an object and if the work done by this force on the object in the time interval Δt is W, the **average power** during this interval is

$$\boxed{P_{avg} = \frac{W}{\Delta t}}$$

- An alternative expression for power can be obtain from the work formula:

$$P_{avg} = \frac{W}{\Delta t} = \frac{F\cos\theta\,\Delta x}{\Delta t} \quad \rightarrow \quad \lim_{\Delta t \to 0} P_{avg} = \lim_{\Delta t \to 0} \frac{F\cos\theta\,\Delta x}{\Delta t} \quad \Rightarrow \quad \boxed{P = F\cos\theta\ v}$$

Units of Power

- The SI unit of power is joules per second (J/s) also called the **watt (W)** after James Watt

$$\boxed{1W = 1\,J/s = 1\,kgm^2/s^2}$$

- A unit of power in the U.S. customary system is the **horsepower (hp)**

$$\boxed{1hp = 746\,W}$$

- A unit of energy (or work) can now be defined in terms of the unit of power.
- One **kilowatt-hour (kWh)** is the energy transferred in 1 hour at the constant rate of 1 kW = 1000 J/s.
- The amount of energy represented by 1 kWh is:

$$\boxed{1\ \mathrm{kWh} = (10^3\ \mathrm{W})(3600\ \mathrm{s}) = 3.60 \times 10^6\ \mathrm{J}}$$

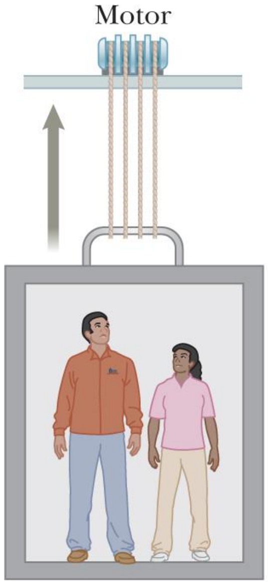
- Note that kilowatt-hour (kWh) is unit of energy, not power.

Power

Example 9 (Power Delivered by an Elevator Motor): An elevator car has a mass of 1600 kg and is carrying passengers having a combined mass of 200 kg. A constant friction force of 4000 N retards its motion.

(a) How much power must a motor deliver to lift the elevator car and its passengers at a constant speed of 3.00 m/s?

Draw the free body diagram of the system



$$\sum F_y = 0 \quad \rightarrow \quad T - f - Mg = 0 \quad \rightarrow \quad T = Mg + f$$

$$\boxed{P = F\cos\theta \ v} \quad \Rightarrow \quad P = T\cos 0° \ v = (Mg + f)v$$

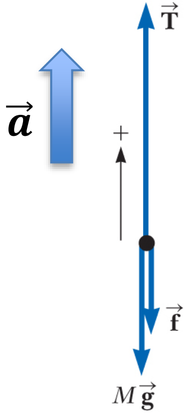
$$\begin{aligned} P &= [(1800 \text{ kg})(9.80 \text{ m/s}^2) + (4000 \text{ N})](3.00 \text{ m/s}) \\ &= 6.49 \times 10^4 \text{ W} \end{aligned}$$

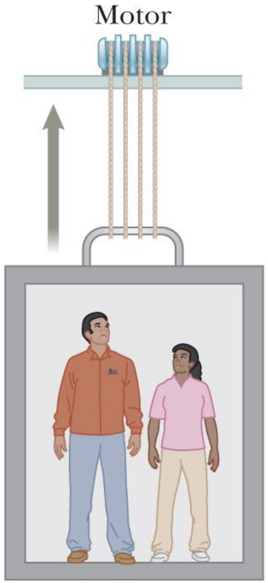
Power

Example 9 (Power Delivered by an Elevator Motor): An elevator car has a mass of 1600 kg and is carrying passengers having a combined mass of 200 kg. A constant friction force of 4000 N retards its motion.

(b) What power must the motor deliver at the instant the speed of the elevator is *v* if the motor is designed to provide the elevator car with an upward acceleration of 1.00 m/s^2?

Draw the free body diagram of the system





$$\sum F_y = Ma \quad \rightarrow \quad T - f - Mg = Ma \quad \rightarrow \quad T = M(a+g) + f$$

$$\boxed{P = F\cos\theta \; v} \qquad P = T\cos 0° \; v = (M(a+g) + f)v$$

$$P = [(1800\text{ kg})(1.00\text{ m/s}^2 + 9.80\text{ m/s}^2) + (4000\text{ N})](3.00\text{ m/s})$$
$$= 7.02 \times 10^4\text{ W}$$

Power

Example 10 (The Power to Accelerate a Car): A car, starting from rest, accelerates in the +*x* direction. It has a mass of 1.10×10^3 kg and maintains an acceleration of +4.60 m/s^2 for 5.00 s. Assume that a single horizontal force accelerates the vehicle. Determine the average power generated by this force.

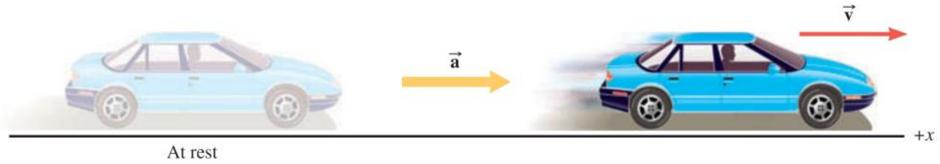
$$\boxed{P = F\cos\theta \;\; v} \quad \Rightarrow \quad P = (ma_x)\cos 0° \left(\frac{1}{2}a_x t\right)$$

$$P = (1.10 \times 10^3 kg)(4.60\, m/s^2)\left(\frac{1}{2}(4.60\, m/s^2)(5.00\, s)\right) = 5.82 \times 10^4\ W$$

$$\sum F_x = ma_x \quad \rightarrow \quad F = ma_x$$

$$v_{avg} = \frac{1}{2}(v_{xi} + v_{xf}) = \frac{1}{2}(v_{xi} + v_{xi} + a_x t)$$

$$v_{avg} = \frac{1}{2}a_x t$$



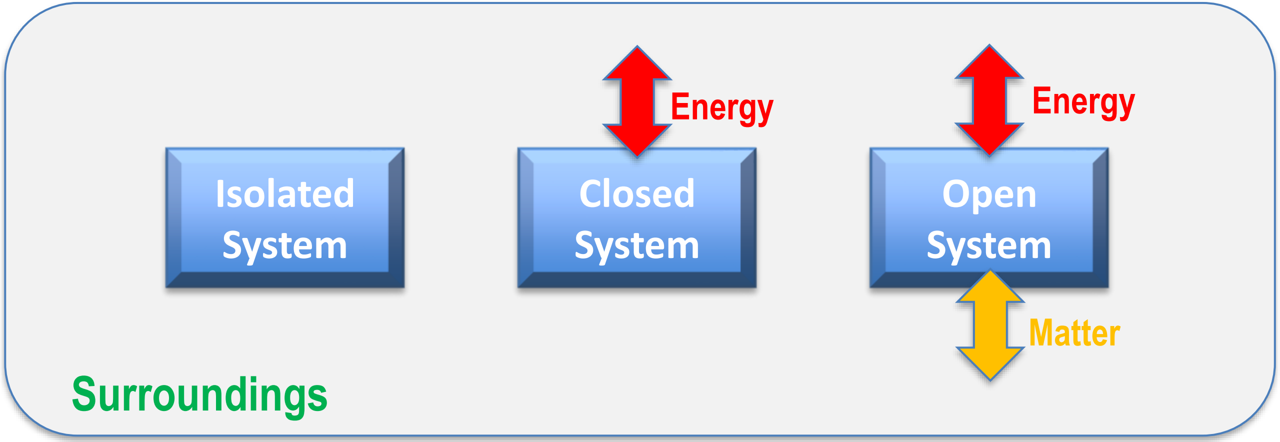
Quick Quiz 3

- What average power is generated by a 70.0-kg mountain climber who climbs a summit of height 325 m in 95.0 min?

    a) 39.1 W
    b) 54.6 W
    c) 25.5 W
    d) 67.0 W
    e) 88.4 W

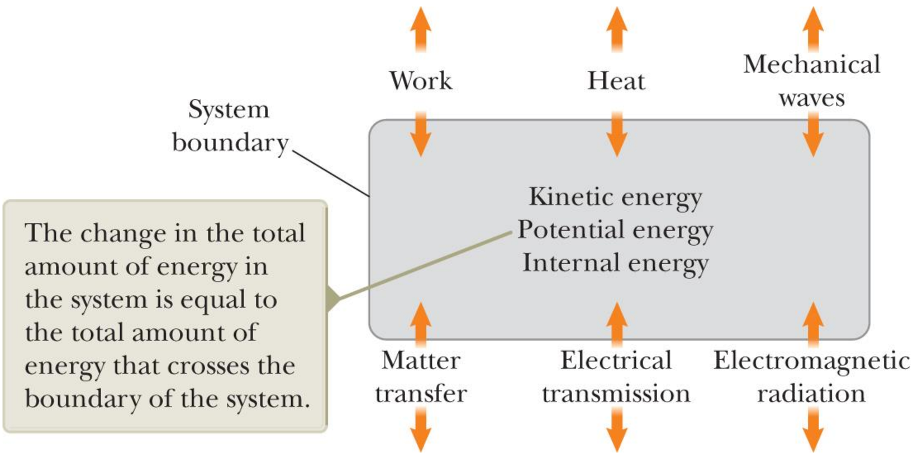
Isolated and Non-Isolated Systems

- A **system**, as it is defined as a collection of objects or smaller systems that can be identified.
- Systems can be described in three different ways:
  - **Isolated System:** A system in which no matter or energy is being exchanged with the surroundings.
  - **Closed System:** A system in which only energy is being exchanged with the surroundings.
  - **Open System:** A system in which both matter and energy is being exchanged with the surroundings.



Energy in Non-Isolated Systems

- The energy can exist in the system in three forms:
  - Kinetic Energy
  - Potential Energy
  - Internal Energy



- In non-isolated systems, the total energy can be changed when energy crosses the system boundary by any of the <u>six transfer methods.</u>

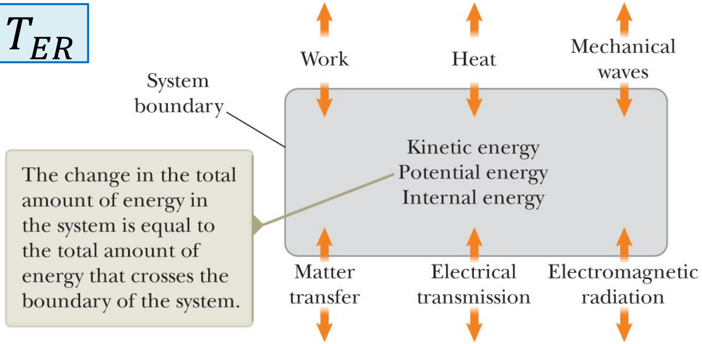
- In non-isolated systems, the conservation of energy equation is expressed as:

$$\boxed{\Delta E_{sys} = \sum T} \Rightarrow \boxed{\Delta K + \Delta U + \Delta E_{int} = W + Q + T_{MW} + T_{MT} + T_{ET} + T_{ER}}$$

Energy in Non-Isolated Systems

- The conservation of energy equation is generally reduced to a simpler form for a specific problem

$$\boxed{\Delta K + \Delta U + \Delta E_{int} = W + Q + T_{MW} + T_{MT} + T_{ET} + T_{ER}}$$



- Consider the following examples of non-isolated systems:

1) Your television set:

$$\Delta E_{\text{int}} = Q + T_{\text{MW}} + T_{\text{ET}} + T_{\text{ER}}$$

2) A cup of tea being warmed in a microwave oven.

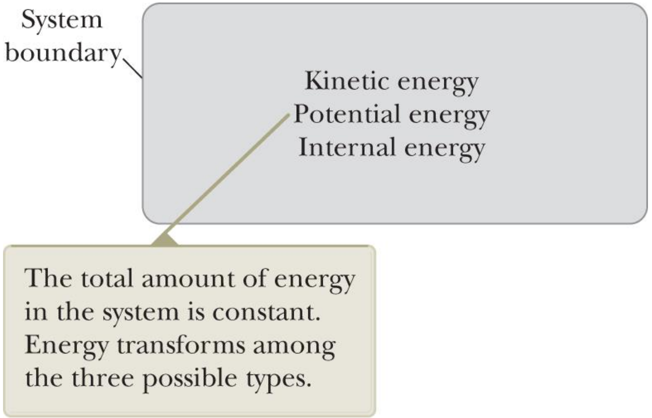
$$\Delta E_{\text{int}} = Q + T_{\text{ER}}$$

3) Your gasoline-powered lawn mower. The time interval includes the process of filling the tank with gasoline.

$$\Delta K + \Delta U + \Delta E_{\text{int}} = W + Q + T_{\text{MW}} + T_{\text{MT}}$$

Energy in Isolated Systems

- The energy can exist in the system in three forms:
  - Kinetic Energy
  - Potential Energy
  - Internal Energy



- In isolated systems, no energy crosses the boundary of the system by any method.
- Then, the system is isolated; energy transforms from one form to another

$$\boxed{\Delta E_{sys} = 0}$$

- If no nonconservative forces act within the isolated system, the mechanical energy of the system is conserved:

$$\boxed{\Delta E_{mech} = \Delta K + \Delta U = 0}$$

- If nonconservative forces, such as friction or air resistance act within the system, there is a change in internal energy:

$$\boxed{\Delta E_{mech} = \Delta K + \Delta U + \Delta E_{int} = 0}$$

Energy in Isolated Systems

- Consider the following examples of isolated systems:

1) An object in free-fall:

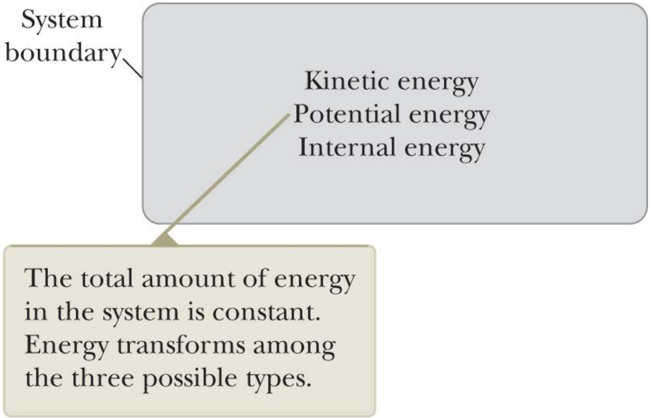
$$\Delta K + \Delta U = 0$$

2) A basketball rolling across a gym floor comes to rest:

$$\Delta K + \Delta E_{int} = 0$$

3) A pendulum is raised and released with an initial speed and its motion eventually stops due to air resistance:

$$\Delta K + \Delta U + \Delta E_{int} = 0$$



$$\boxed{\Delta E_{mech} = \Delta K + \Delta U = 0}$$

$$\boxed{\Delta E_{mech} = \Delta K + \Delta U + \Delta E_{int} = 0}$$

Quick Quiz 4

- Consider a block sliding over a horizontal surface with friction. Ignore any sound the sliding might make.

If the system is the ***block***, this system is

a) Isolated
b) Non-isolated
c) Impossible to determine

If the system is the ***surface***, this system is

a) Isolated
b) Non-isolated
c) Impossible to determine

If the system is the ***block and the surface***, this system is

a) Isolated
b) Non-isolated
c) Impossible to determine

THANK YOU

HUMBER

WE ARE HUMBER