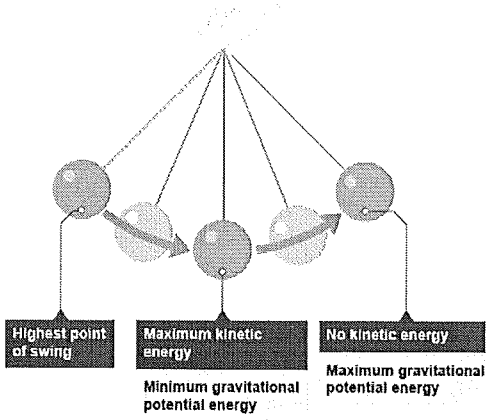
Lesson 7: Conservation of Energy

In any closed system the TME (Total Mechanical Energy) remains constant. When energy is transferred or transformed the TME remains constant. This is the law of conservation of energy.



The Law of conservation of energy can also be stated as $\Delta KE + \Delta PE = 0$. Where ΔKE means change in kinetic energy, $KE_{final} - KE_{initial}$. ΔPE means change in potential energy, $PE_{final} - PE_{initial}$.

Example: As 10 kg rock falls from a height of 10m to the ground it loses gravitational potential energy. Determine the change in gravitational potential energy.

$$\Delta PE = PE_{final} - PE_{initial}$$

$$mgh_{final} - mgh_{initial}$$

$$10kg \times 9.8m/s^2 \times 0m - 10kg \times 9.8m/s^2 \times 10m$$

$$-980\ J$$

Note the negative sign indicates a loss in energy.

What is the gain in kinetic energy of this rock? The rock must gain 980J of kinetic energy.

The final velocity of the falling rock can now be found using $\Delta KE = 980$ J.

$$KE_{final} - KE_{initial} = 980$$

$$1/2mv^2_{final} = 980$$

$$mv^2_{final} = 2 \times 980$$

$$10 \times v^2_{final} = 1960$$

$$v^2_{final} = 196$$

$$V_{final} = 14m/s$$

1. Complete the following table.

	Variable used	Units measure in	Unit symbol
Kinetic Energy	KE or E_k	Joules	J
Potential Energy	PE or E_p	Joules	J
Mass	m	kilograms	kg
Gravitational Field Strength	g	N/kg	g
Velocity	v	m/s	v
Height	h	meters	m

Remember...
PE=KE

$mgh=1/2mv^2$

$\cancel{m}gh=1/2\cancel{m}v^2$

$gh=1/2v^2$

$2gh= v^2$

$\sqrt{2gh} = v$

$\cancel{m}gh = \frac{1}{2}\cancel{M}v^2$

$h = \frac{v^2}{2g}$

2. A 20.0 kg boulder is at a height of 152 metres above the ground.

a) Determine its potential energy.

$PE = mgh = 20.0kg \times 9.8N/kg \times 152m$

$= 29,792\ J$

b) Determine its kinetic energy.

Since it is not moving $V=0$ so KE is 0

c) It releases from the cliff and falls to the ground. What is the boulder's impact velocity (how fast it hits the ground)?

Since it had 29,792 J of PE it now has 29,792 J of KE as it hits ground....

$v = \sqrt{2gh} = \sqrt{2(9.8) \times 152m} = 55m/s$

3. A 180 kg boulder falls off a cliff and hits the ground at 45 m/s.
What height is the cliff?

$h = \frac{v^2}{2g} = \frac{(45m/s)^2}{2(9.8)} = 103\ m$

4. What is the initial potential energy of the boulder?

$PE = mgh = 180\ kg \times 9.8\ N/kg \times 103\ m$

$= 181,692\ J$

5. What is the final potential energy of the boulder?

0 J because it is on the ground and $h = 0$

6. A cannon launches a 3.5 kg cannonball vertically upwards at 89 m/s. What maximum height will the cannonball reach?

$h = \frac{v^2}{2g} = \frac{(89\ m/s)^2}{2(9.8)} = 404\ m$

7. What is the initial kinetic energy of the cannonball?

$KE = \frac{1}{2} m v^2 = \frac{1}{2} \times 3.5\ kg \times (89\ m/s)^2$

$= 13,861.75\ J$

8. What is the final kinetic energy of the cannonball?

at the top of the ball's travel its $V = 0$ so KE is 0 at the top of its path

Additional Practice:

1. According to the Law of Conservation of Energy, the total amount of energy in the universe a.
   a) Remains constant
   b) Decreases
   c) Increases
   d) Changes constantly

2. A basketball is dropped outside of the school. If it reaches the floor at a speed of 3.2 m/s, from what height did it fall?

$$h = \frac{v^2}{2g} = \frac{(3.2\ m/s)^2}{2(9.8)} = 0.522\ m$$

3. A safe is hurled down from the top of a 130 m building. What is its velocity as it hits the ground?

$$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 130\ m}$$

$$= 50.5\ m/s$$

4. A 2.5 kg object is dropped from a height of 10.0 m above the ground. Calculate the speed of the object as it hits the ground.

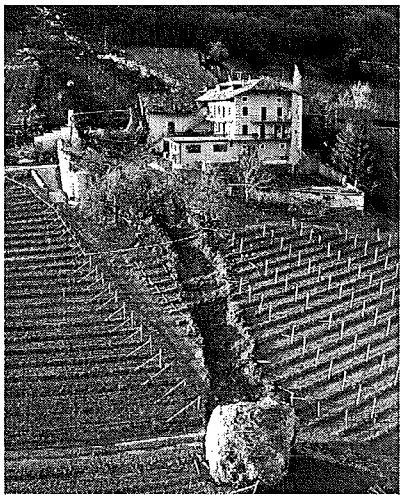
$$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 10.0\ m} = 14\ m/s$$

5. A 200-kg boulder is 1000-m above the ground.
   a) What is its potential energy when it is 1000-m above the ground?

$$PE = mgh = 200\ kg \times 9.8\ N/kg \times 1000\ m = 1{,}960{,}000\ J$$

   b) What is its kinetic energy when it is 1000-m above the ground?

Since its $v = 0$ the PE is 0



c) The boulder begins to fall. What is its potential energy when it is 500-m above the ground? Where did the "lost" potential energy go?

$PE = mgh = 200\,kg \times 9.8 \times 500\,m$

$= 980{,}000\,J$

d) What is the kinetic energy of the boulder when it has fallen 500-m?

KE + PE = total Energy

Total E − PE = KE

1,960,000 − 980,000 = 980,000

e) What is the kinetic energy of the boulder just before it hits the ground?

Since all the energy is KE (as it hits the ground) the KE is 1,960,000J as the PE is 0

6. A boulder sits atop a steep cliff and someone pushes it off the edge. If the cliff is 45 metres high and the boulder is 200kg, what speed will the boulder hit the ground with? Ignore air friction in this case.

$v = \sqrt{2gh}$

$= \sqrt{2(9.8) \times 45} = 29.7\,m/s$

7. A child with a mass of 25.5 kg starts at rest and goes down a slide with a height of 3.50 m

What is speed at bottom?

$v = \sqrt{2gh} = \sqrt{2(9.8) \times 3.50\,m}$

$= 8.3\,m/s$

8. **Challenge**... Silverstar, a Roller Coaster in Germany is 78m high at its tallest point. The total mass of the carts is 537 kg. With what speed would the cart be travelling at the bottom of the roller coaster if the cart had a speed of 5 m/s at the top of the roller coaster?

total E = PE + KE

$= mgh + \frac{1}{2}mv^2$

$= (537 \times 9.8 \times 78) + \left[\frac{1}{2} \cdot 537 \times (5\,m/s)^2\right]$

$= 417195\,J$

At bottom $KE = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(417195)}{537\,kg}}$

$= 39.4\,m/s$