Kinetic and Gravitational Potential Energy

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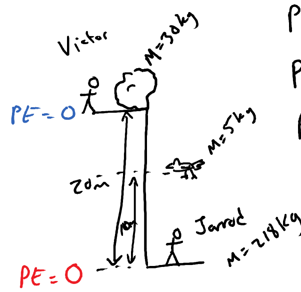
Potential Energy is a type of energy that an object has due to its relative position to a state of equilibrium. An object that is compressing a spring is giving the spring potential energy that can be released and turned into motion.

Gravitational Potential Energy is given to an object by changing the objects height or distance away from a large gravitational body such as the earth.

$$W = \Delta E = F \cdot d$$
$$= F_g \cdot h$$
$$\boxed{PE = mgh}$$

h = height above or below zero



relative to the bottom

$PE_R = (30)(9.8)(20)$
$= 5880\ J$
$PE_B = (5)(9.8)(10)$
$= 490\ J$
$PE_J = 0\ J$

relative to the top

$PE_R = (30)(9.8)(0)$
$= 0$
$PE_B = (5)(9.8)(-10)$
$= -490\ J$
$PE_J = -42728\ J$

$PE = mgh$

The work down to change an objects height on earth gives the object Gravitational Potential Energy. This Potential Energy can be used to give the object motion.

You define PE=0

PE=0 —— ↑ PE > 0 ↓ PE < 0

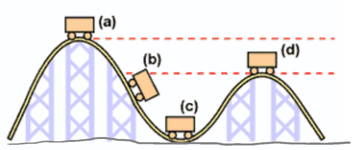
Potential Energy (Scalar)
Symbol: PE or E_p
Units: Joules (J) - no direction

PE = mgh

*A key mistake that students make is with knowing whether the object has positive or negative potential energy. In our questions we must always define a point to have zero potential energy. Any position higher than that point will have positive and any point below will have negative potential energy.

Ex 1: What is the potential energy of the cart at the following heights above ground? (a=12m, b=7m, c=0m, d=8m)

M = 50 Kg



$PE = mgh$

$PE_a = 5880\ J$
$PE_b = 3430\ J$
$PE_c = 0\ J$
$PE_d = 3920\ J$

Ex 2: An object is lifted 1.3m up off a 1.7m tall table. m = 37 kg

a) What is the objects Potential Energy relative to the table top?

1.7m 0 1.3m

$PE = mgh$
$= (37)(9.8)(1.3)$
$= 471\ J$

b) What is the objects Potential Energy relative to the ground?

$(1.3 + 1.7) = 3$
$PE = mgh$
$= (37)(9.8)(3) = 1088\ J$

c) What is the objects Potential Energy when it is 1m off the ground relative to the table top?

1.7m 0 1m

$PE = mgh$
$= (37)(9.8)(-0.7)$
$= -254\ J$

Kinetic Energy is the energy an object has due to its relative velocity.

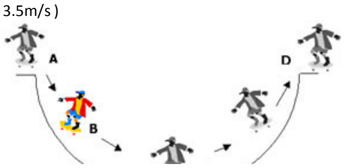
Kinetic Energy (Scalar)
Symbol: KE or E_k
Units: Joules (J) - No direction

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

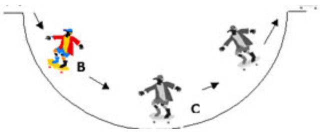
*Kinetic Energy is always POSITIVE because we never have negative mass and the velocity is squared.

Ex 1: What is the kinetic energy of the skate boarder at the following velocities? (VA = 0m/s VB = 7.5m/s VC=12.5 VD = 3.5m/s 3.5m/s)

M = 65 kg



$KE_A = 0\ J$
$KE_B = \frac{1}{2}(65)(7.5)^2 = 1828\ J$
$KE_C = \frac{1}{2}(65)(12.5)^2 = 5078\ J$



$KE_A = 0\,J$
$KE_B = \frac{1}{2}(65)(7.5)^2 = 1828\,J$
$KE_C = \frac{1}{2}(65)(12.5)^2 = 5078\,J$
$KE_D = \frac{1}{2}(65)(3.5)^2 = 398\,J$

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

Ex 2: In the previous unit we studied the change in momentum of a car hitting a wall a 25m/s and rebounding with a velocity of -20m/s. What is the Kinetic Energy of the car at these two velocities? $m = 1300kg$

25m/s
$KE = \frac{1}{2}mv^2$
$= 406250\,J$

-20m/s
$KE = \frac{1}{2}(1300)(-20)^2$
$= 260{,}000\,J$

Temperature is the measure of the average kinetic energy of the molecules in an object. These molecules vibrate and move causing motion. Due to the amount of molecules an object has it is impractical and even impossible to measure the kinetic energy of each object. Instead we use statistics to find the average kinetic energy and thus the Temperate of the object.

Temperature (Scalar)
Symbol: T
Units: Kelvin (K) - no direction

*Temperature is most commonly measured in Celsius and Fahrenheit. In science we use Kelvin. Kelvin is just like Celsius except rather than zero being the point at which water freezes, in Kelvin zero is the point at which all matter stops moving and vibrating. It is the absolute zero point.

Absolute Zero, 0 K is equivalent to -273.16°C. The scale is the same for Kelvin and Celsius but they simply chose a different starting point. Kelvin has a one to one relationship to Celsius (ie. A change of 5°C is also a change of 5 K).

Fun Temperatures:
- Space: 2.7K
- Oxygen Liquifies at 90K
- Oxygen Freezes at 54K
- Helium liquifies at 4.4K and becomes a super fluid at 2K
- Sun surface ~6000K inner core ~15,000,000K

There is no known upper limit to Temperature but matter turns into a plasma state at around 10^8K. Plasma is an ionized gas where electrons stop being bound to a single atom and instead flow freely around.

Changing from Celsius to Kelvin
Ex 1: Water boils at 100°C. What is this temperature in Kelvin?

$T_K = T_C + 273.16$
$= 100 + 273.16$
$= 373.16\,K$

Ex 2: A lady burned herself with a McDonalds Coffee, sued them for millions and won. The coffee was at 395K. What was the temperature in Celsius?

$T_K = T_C + 273.16$
$395 - 273.16 = T_C$
$121.84°C = T_C$

Thermal Energy In this class we will be looking at the relationship between an objects change in Temperature and how this produces Thermal Energy.

Thermal Energy (Scalar)
Symbol: Q
Unites: Joules (J) - no direction

$$Q = mC\Delta T$$

*C is the specific Heat Capacity of a particular substance. This is a constant that is unique for each substance. Below is a list of some common specific Heat Capacity.

Material	Specific Heat (J kg^{-1} K^{-1})
Aluminium	878
Copper	381
Iron	438
Lead	126
Ethanol	2410
Water	4200
Hydrogen	14150

Ex 1: What is the Thermal Energy Released of a 340g cup of coffee as it cools from 97°C to 35°C (Specific Heat of Coffee = 4180 J/kg/K)?

$Q = mC\Delta T$

$0.340\,kg$

$\Delta T = T_f - T_i$

$= 35°C - 97°C$

$= -62°C$ or $-62K$

$Q = (0.340)(4180)(-62)$

$Q = -88114\,J$

$\boxed{\text{This means a loss of } 88114\,J}$

Ex 2: A bath tub holding 130 litres of water is at 78°C. How many litres of 110°C water needs to be added to raise the temperature up to 98°C? (1kg = 1litre)

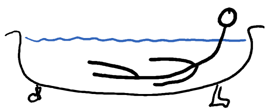
Initially $m = 130\text{ litres} = 130\,kg$

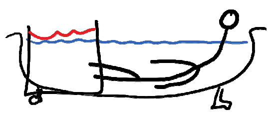
$T_i = 78°C$

Finally $m = 130\,kg$

$T_F = 98°C$

Cold

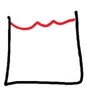




$Q_c = mC\Delta T$

$Q_c = (130)(98-78)\,C$

Hot



$m = x$

$T_i = 110°$

$m = x$

$T = 98°C$

$Q_H = mC\Delta T$

$Q_H = x(98-110)\,C$

$$Q_c = -Q_H$$

$$130(98-78)\cancel{C} = -x(98-110)\cancel{C}$$

$$\frac{(130)(20)}{12} = \frac{12x}{12}$$

$$x = 217\,kg$$