Unit Four

Work, Energy and Power

Learning Outcome

After completing this unit, students are expected to:

- understand the concepts of work, energy, and power.
- express these quantities in mathematical formula.
- solve problems based on these concepts.
- describe the necessary conditions for work to be done.
- calculatework done by variable force and work done against gravity and against friction.
- distinguish between positive and negative work
- explain the relationship between work and energy.
- derive the relationship between work and kinetic energy and use this to solve problems.
- show the relationship between work and potential energy W = $-\Delta U$
- describe the mechanical energy as the sum kinetic energy and potential energy.
- stale the law of conservation of mechanical energy.
- describe the use of energy resources.
- define the term power and calculate it using its formula.
- express the formula of mechanical power in terms of average velocity.

Introduction

This chapter introduces: meanings of work done, kinetic and potential energies, power and how each of these are calculated using a given quantities. Problems are considered from different corners of real life within the context of simplified models.

4.1 The Concept of Work

Work and energy are important concepts in physics as well as in our everyday lives. In physics, a force does work if its point of application moves through a distance and there is a component of the force in the direction of the displacment of the force's point of application. For a constant force in one dimension, the work done equals the force component in the direction of the displacement times the displacement. (This differs somewhat from the everyday use of the word work. When you study hard for an exam, the only work you do according to the use of the word in physics, is in pushing your pencil on the paper, or turning the pages of your book.)

Energy is closely associated with work. They are like two faces of the coin. They cannot separate to each other. The energy of an object is a mathematical representation of the amount of work the object can do. It is ability (capacity) to do work. On the other hand, when work is done by one system on another, energy is transferred between the two systems. For example, when you do work pushing a swing, chemical energy of your body is transferred to the swing and appears as kinetic energy of motion or as gravitational potential energy of the earth-swing system. There are many forms of energy. Kinetic energy is associated with the motion of an object. Potential energy is associated with the configuration of a system, such as the separation distance between two objects that attract each other (gravitational potential energy) or due to stretching or compressing of elastic materials (elastic potential energy). Thermal energy is associated with the random motion of the molecules within a system and is closely connected with the temperature of the system. Some other forms of energy are: Electrical, Nuclear, Chemical, sound, wind energy, e.t.c.

4.1.1. Work done by a constant force

We consider an object that is displaced along the x axis by $\Delta \boldsymbol{x}$ by applying a constant force $\boldsymbol{F}$ that makes an angle $\boldsymbol{\theta}$ with the direction of motion, as shown in Fig. 6.1.

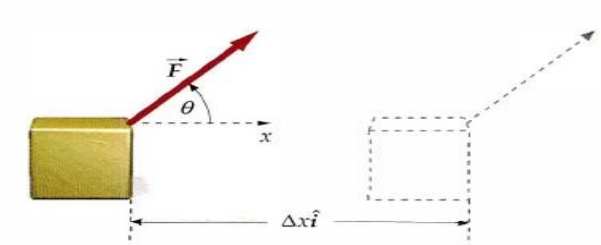


Fig. 4.1.1 Work done by a constant force

Then the work done on the object by the constant force (constant in both magnitude and direction) is defined as the product of the magnitude of the displacement times the component of the force parallel to the displacement. That is,

$$W = \Delta x F cos\theta,$$

where $Fcos\theta$ is the component of the force in the direction of the displacement, W is work done, and Δx is the magnitude of the displacement. We notice that work done can be positive, negative or zero depending on the angle θbetween the force and the displacement. The work done is positive when the force has a component in the same direction as the displacement ($0^0 \leq \theta < 90^0$). On the other hand, when the force has a component opposite to the displacement ($90^0 < \theta \leq 180^0$), the work done is negative. When the force is perpendicular to the displacement, $\theta = 90^0$and the work done by the force is zero.

Work is said to be done on an object by a force if (a) the force is not perpendicular to the displacement ($\theta \neq 90^0$); and (b) the force displaces the object. For instant, a person pushing a fixed wall is not doing work since there is no displacement.

Moreover, a person carrying a quintal of teff and moving horizontally is not doing work. In this case the force applied on the quintal is vertically upward and the displacement is in the horizontal direction. If an applied force **F** is in the same direction as the displacement Δx, then $\theta = 0$and cos 0 =1.
In this case, the above Equation gives
$W = F\Delta x$

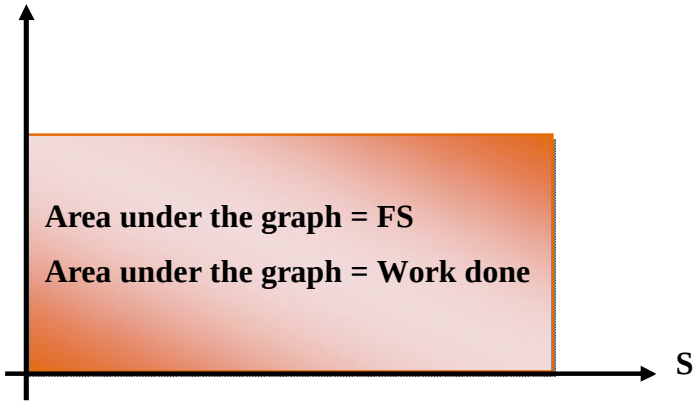


Fig. 4.1.2 Plot of Force Vs distance

Work is a scalar quantity, and its units are force multiplied by length. Therefore,the SI unit of work is the **Newton. meter (N· m).** This combination of units is used sofrequently that it has been given a name of its own: the **joule (J).**

Plot of force against distance

We can plot a **graph** of the force applied againstthe distance travelled against the force. The area under a force vs. distance moved graph is equal to the work done.The plot in the Figure indicates graph of constant force actingover a distance.

Example1

If you push a box 20 m forward by applying a force of 15 N in the forward direction, what is the work you have done on the box?

Solution:

The force applied is F=15 N.

• The distance moved is s=20 m.

• The applied force and distance moved are in the same direction. Therefore, $F_{||}$=15 N. Thus, the work is

$$W = F_{||}s$$
$$= (15\ N)(20\ m)$$
$$= 300\ J$$

Example 2

What is the work done by you on a car, if you try to push the car up a hill by applying a force of 40 N directed up the slope, but it slides downhill 30 cm?

Solution:

• The force applied is F=40 N

• The distance moved is s=30 cm=0.3m.

• The applied force and distance moved are in opposite directions. Therefore, the angle between them is $\theta = 180^0$. Thus , the work done by the force is

$$W = F\cos 180^0$$
$$= (-40N)(0.3m)$$
$$= -12J$$

Example 3.

Calculate the work done on a box, if it is pulled 5 m along the ground by applying a force of F=10 N at an angle of 60◦ to the horizontal.

Solution:

• The force applied is F=10 N

• The distance moved is s=5 m along the ground

• The angle between the applied force and the motion is 60^0.

Thus the Work done is

$W = F\cos 60^0$

$= (5N)(5m)$

$= \underline{\mathbf{25\ J}}$

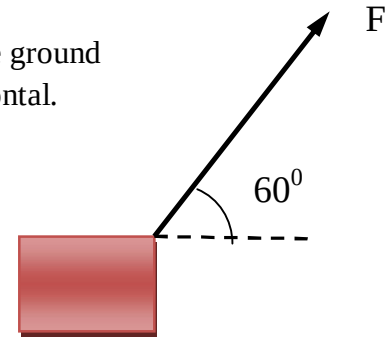


Figure 4.1.3 Work done by constant force

Doing work against gravity

Work is often done against gravity. Whenever you lift up an object you are doing work against the force of gravity. We can adapt our work done equation for working against gravity:

$W = F\ s$

Work done against gravity = weight × vertical distance moved

Or $W_{gravity} = w \times h = mgh$

Example: The work done in lifting a 60 kg mass vertically 3 m can be found using the work done equation:

$W_{gravity} = w \times h$

The weight is $w = mg = 60\ kg \times 10\ N/kg = 600\ N$

$W_{gravity} = 600\ N \times 3\ m$

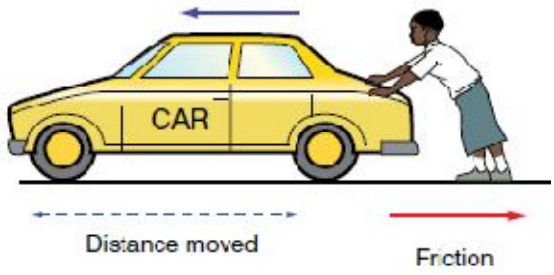
$W_{gravity} = 1800\ J$

Work done against kinetic friction

We recall that whenever you push or pull an object along the ground you are doing work against a force of kinetic friction. In Unit 3 we learnt that the kinetic friction is given as

$$f_{kinetic} = \mu_{kinetci} N$$

Kinetic friction always acts in the opposite direction to motion' that is the kinetic friction and the displacement makes 180^0.
Thus applying our work done equation, the work done by friction is given as



$$W_{friction} = f_{kinetic}\, s\, \cos 180^0$$
$$W_{friction} = -f_{kinetic}\, s = -\mu_{kinetci}\, s\, N$$

This result indicates that frictional force always does negative work. Its effect is always to decrease the energy of the body on which it is doing work.
Note that the work done against friction is the negative of the work done by friction and is expressible as

$$W_{against\ friction} = f_{kinetic}\, s = \mu_{kinetic}\, s\, N$$

Example: Determine the work done in pushing a 100 kg wooden block 30 m across a horizontal concrete floor with $\mu_{kinetic}$= 0.48
Solution:The work done against friction is given as

$$W = \mu_{kinetic} N\, s$$

In this case the normal contact force is equal to the weight (as the floor is horizontal) and so

$$N = w = mg$$
$$N = 100\ kg \times 10\ N/kg = 1000\ N$$
$$W = \mu_{kinetic} N \times s$$
$$W = 0.48 \times 1000\ N \times 30\ m$$
$$W = 14\ 400\ J \text{ or } 14.4\ kJ$$

This energy has been transformed into **heat energy** where the block and surface rub together.

Work done against Gravity and friction
If you were to push or pull on an object up a ramp then you end up doing work against both friction and gravity. In this case the total work done could be found using the following equation:

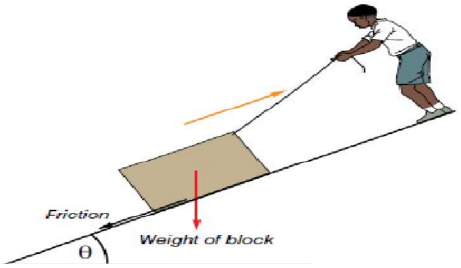


Figure 4.1.4 Work done against gravity

Total work done = work done against gravity +work done against friction

$W_{total} = W_{against\ gravity} + W_{against\ friction}$

$W_{total} = (w \times h) + (\mu_{kinetic} N \times s)$

We have to be very careful in considering the distances
we use in this equation; h has to be the vertical distance,
as this is the distance moved against gravity, whereas s must be the distance moved up the slope as friction acts down the slope.

Example 1: A block of mass 4kg is pushed along an inclined plane that makes $45^0$from the horizontal. If the coefficient of friction between the plane and the block is 0.2, find the total work done on the in pushing it 4m along the plane.

Solution:

M=4kg, S=4m $\theta=45^0$, μ =0.2

What is required is W_{total}?

$W_{total} = W_{against\ gravity} + W_{against\ friction}$

$W_{total} = (w \times h) + (\mu_{kinetic} N \times s)$

$= (mg\ s \sin\theta) + (\mu_{kinetic} mg\cos\theta s)$

$=(4kgx10m/s^2x4m\ x\ 0.7)+(0.2x4kgx10m/s^2x0.7x4m)$

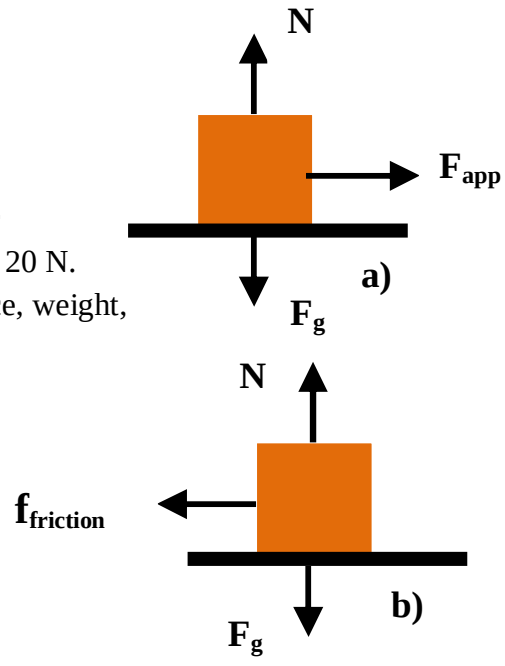
$=112J+22.4J=134.4J$

Review Questions

1. A 10 N force is applied to push a block across a friction free surface for a displacement of 5.0 m to the right. Fig(a) The block has a weight of 20 N. Determine the work done by the following forces: normal force, weight, applied force.

2. A 10 N frictional force slows a moving block to a stop after a displacement of5.0 m to the right. The block has a weight of 20 N. Determine the work done by the following forces: normal force, weight, frictional force Fig (b).

3. A 10 N force is applied to push a block across a frictional surface at constant speed for a displacement of 5.0 m to the right. The block has a weight of20 N and the frictional force is 10 N. Determine the work done by the following forces: normal force, weight, frictional force Fig (c).



4. A 20 N object is sliding at constant speed across a friction free surface for a displacement of 5 m to the right. Determine if there is any work done Fig (d).

5. A 20 N object is pulled upward at constant speed by a 20 N force for a vertical displacement of 5 m. Determine if there is any work done Fig. (e).

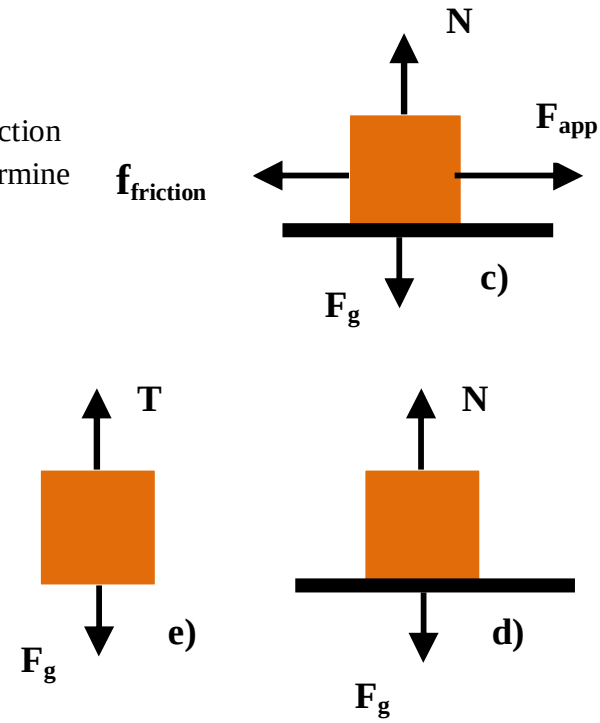


Figure 4.1.5: Work done with constant force

4.1.2. Work done by a varying force

If a force is variable (for example if it varies with position) , we cannot use $W=F\Delta x\cos\theta$ to calculate the workdone by the force because this relationship applies only when F is constant in magnitude and direction. However, for a force that varies uniformly with the displacement, the work done can readily be calculated by multiply the average of the magnitude of the force over the displacement by the magnitude of displacement if they are parallel

$$W= F_{av}\Delta x$$

Since the force varies uniformly, the average force is $F_{av}= \frac{F_i+F_f}{2}$, where F_i *and* F_f are the initial and final force, thus the work is given as

$$W= (\frac{F_i+F_f}{2})\Delta x$$

Example: A force acting a body varies uniformly from 20N to 40N in displacing the body by 5m along the direction of the displacement. Calculate the work done by the force.

Solution: The average force is

$$F_{av}= \frac{F_i+F_f}{2} = \frac{20N+40N}{2} = 30N$$

The work done by the force can be calculated as

$$W= F_{av}\Delta x = 30N\ X5m = 150J$$

Work done by a spring force

A block on a horizontal, frictionless surface is connected to a spring. If the spring is either stretched or compressed a small distance from its unstretched (equilibrium) configuration, it exerts a force on the block a force that can be expressed using Hook's law as

$$F=-kx$$

where x is the position of the block relative to its equilibrium (x =0) position. The force varies linearly with x.

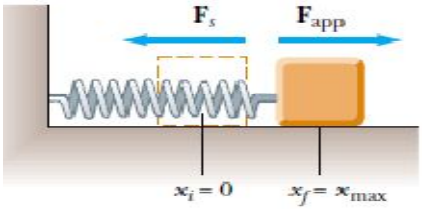


Figure 4.1.6: Work done by a spring

If the block undergoes an arbitrary displacement from an initial position say x_i to final position say x_f , then the work done by the spring W_s from x_i to x_f, is given as

$W_s=F_{av}\Delta x=W= (\frac{F_i+F_f}{2})\Delta x$, where $F_i = -kx_i$ and $F_f= -kx_f$, $\Delta x = x_f-x_i$

$$W_s= -k\left(\frac{x_i+x_f}{2}\right)(x_f - x_i) = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2 \text{(work done by a spring force).}$$

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

This work done by the spring force W_s can have a positive or negative or zero value, depending on whether the ***net*** transfer of energy is to or from the block as the block moves from x_i to x_f.

Caution*:* The final position x_f appears in the ***second*** term on the right side.

Case-1: If x_i = 0 and the final position x

$W_s= = \frac{1}{2}kx^2$

Case-2: When $x_i=x_f$, then W= 0

Case-3: When the spring is stretched, $x_i<x_f$, then W_s is negative or W< 0

Case-4: When the spring is compressed, $x_i>x_f$, then W_s is positive or W > 0

4.1.3 The work done by a force applied on a spring

Now let us consider the work done on the spring by an ***external agent*** that stretches the spring very slowly and steadily (from rest) from x_i to x_f. The applied force increases uniformly up to the elastic limit of the spring.

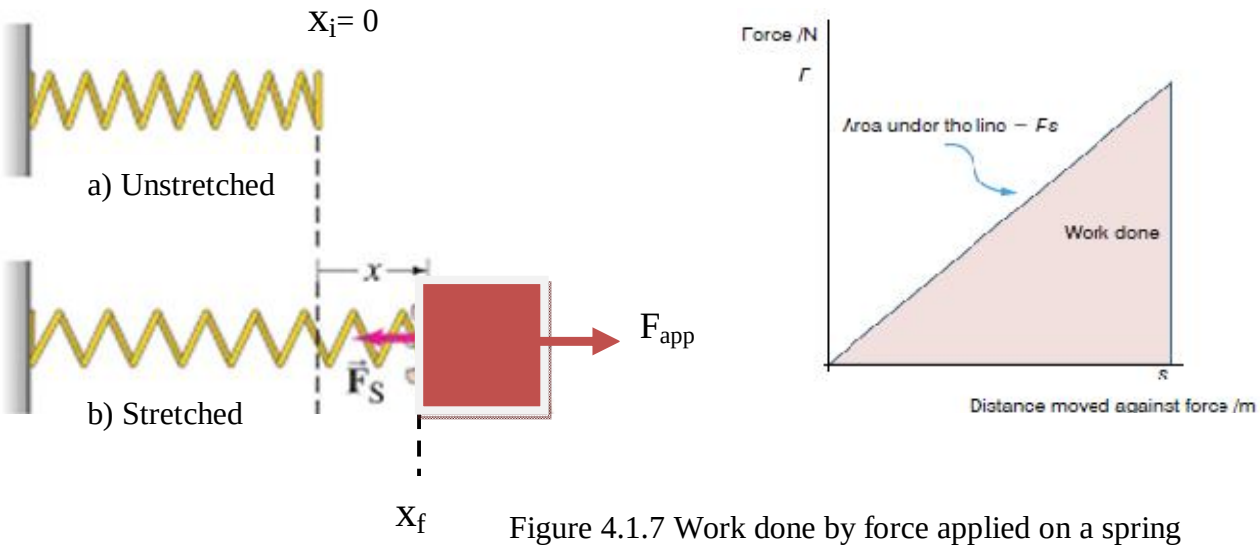


Figure 4.1.7 Work done by force applied on a spring

Then the applied force $\mathbf{F}_{app}$ or $\mathbf{F}_p$ is equal in magnitude and opposite in direction to the spring force $F_S = -kx$ so that $F_{app} = -(-kx) = kx$. Therefore, the work done by this applied force (the external agent) on the block–spring system is

Work done by the applied force = −Work done by a spring

$$W_{app} = -W_s$$
$$= -\left(\frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2\right)$$
$$= \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2$$

Graph of force that varies linearly position. For example the graph may represent the force exerted on a block–spring system.

The work done by the force as the block moves from x= 0 to final x is the area of the shaded triangle

Area under the graph = Work done

$$= \frac{1}{2}\boldsymbol{kx^2}.$$

Example 1: A spring has force constant 100N/m. How much work is done by a boy that compress the spring by 20cm from its equilibrium position?

Solution:

K=100N/m , x= 0.2m

What is required is W_{app}?

$W_{app} = \frac{1}{2}kx^2 = \frac{1}{2}100\ \mathrm{N/m}\,(0.2\mathrm{m})^2$

$W_{app} = 2\mathrm{J}$

4.2 Kinetic energy and work-energy theorem

Kinetic Energy

Kinetic energy *KE* is energy associated with the *state of motion* of an object. The faster the object moves, the greater is its kinetic energy. When the object is stationary, its kinetic energy is zero. For an object of mass *m* whose speed *v* is well below the speed of light

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

Example 1.

A 3.0 kg duck flying past us at 2.0 m/s has a kinetic energy of 6.0 $kg/m^2/s^2$; that is, we associate that number with the duck's motion. Thus, the flying duck has a kinetic energy of 6.0 J.

Example 2.

An1800kg car travelling at a steady speed is acquired a kinetic energy of 3240kJ. What was thespeed of the car?

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

$3240000J=\frac{1}{2}(1800kg)v^2$

$V^2=3240000/900m^2/s^2$

$= 3600\ m^2/s^2$

$V=\sqrt{3600}m/s = 60m/s$

Work and kinetic energy

The total work done on a body by external forces is related to the body's displacement-that is, to changes in its position. But the total work is also related to changes in the speed of the body. Consider a particle with mass m moving along the x-axis under the action of a constant net force with magnitude F directed along the positive x-axis (Fig. 4.2.1). Suppose the speed changes from v_1 to v_2 while the particle undergoes a displacement $\Delta x = \boldsymbol{x_1 - x_2}$ from point x_1 to x_2.

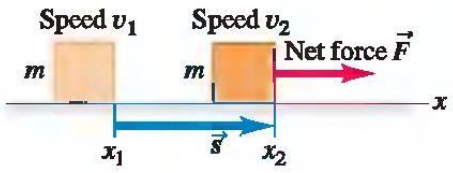


Fig. 4.2.1 Block acted upon by net force

This constant net force on the object is given by Newton's second law as

$$\boldsymbol{F} = m\boldsymbol{a}$$

Now since the force is constant, the acceleration will also remain constant and thus can be written as

$$a = \frac{v_2^2 - v_1^2}{2s}$$

Upon combining the above Equations, the net force is expressible as

$$F = m\frac{v_2^2 - v_1^2}{2s} \quad \text{or}$$

$$Fs = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

The product Fs is the work done by the net force and the quantity

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

is called **kinetic energy** of a mass m moving with speed v. It is energy due to the motion of an object. Thus, $\frac{1}{2}mv_2^2$ is the final kinetic(KE_f) energy of the mass and $\frac{1}{2}mv_1^2$ is its initial kinetic energy (KE_i). Thus one can write

$$W_{net} = KE_f - KE_i$$

We therefore observe that this Equation relates the work done on an object by a net force to the change in its kinetic energy and is known as w***ork-energy theorem.***

Then work-energy theorem can then be stated as the work done by a net force on an object is equal to the change in its kinetic energy.

The work–kinetic energy theorem indicates that the speed of an object *increases* if the net work done on it is ***positive*** because the final kinetic energy is greater than the initial kinetic energy. The speed ***decreases*** if the network is ***negative*** because the final kinetic energy is less than the initial kinetic energy. On the other hand, no work is done by the net force in moving an object with a constant speed.

Example 1: A car of mass 2000kg is changing its speed uniformly from 10m/s to 30m/s through a distance of 800m. a) What is the net work done by the car? b) What was the average net force acting on the car?

Solution:

Given quantities are:

m= 2000kg u=10m/s^{2}V=30m/s^{2}S=800m

a) W=?

$W = \Delta KE$

$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \frac{1}{2}(2000)(30)^2 - \frac{1}{2}(2000)(10)^2$

=900000J-100000J

=<u>800000J</u>

b) F=?

W= FS

F=W/S= 800000J/800m

=1000N

Example 2: A 61 kg skier on level snow coasts 184 m to a stop from a speed of 12.0 m/s. Use the work– energy principle to find the coefficient of kinetic friction between the skis and the snow.

Solution:

$m = 61\ kg,\quad s = 184m,= 12.0\ m/s,\ v_f = 0\ m/s,\quad \mu_k = ?$

According to the work-energy theorem, the change in the kinetic energy of the skis is equal to the work done by the net force acting the skis. That is,

$$W_{net} = K_f - K_i$$

The net horizontal force on the skis is the kinetic frictional force,

$$f_k = \mu_k F_N = \mu_k mg$$

Consequently, the work done by the net force is equal to the work done by frictional force. We thus have

$W_{net} = -f_k s = -\mu_k mgs$ Using the given values, we obtain

$$-\frac{1}{2}mv_i^2 = -\mu_k mgs$$

$$\mu_k = \frac{v_i^2}{2gs} = 0.039$$

Review Questions

1. Describe the relationship between an object's kinetic energy and its:
(a) mass and
(b) velocity
2. A stone with a mass of 100 g is thrown up into the air. It has an initial velocity of 3 $m \cdot s^{-1}$. Calculate its kinetic energy
(a) as it leaves the thrower's hand.
(b) when it reaches its turning point.
3. A car with a mass of 700 kg is travelling at a constant velocity of 100 $km \cdot hr^{-1}$.Calculate the kinetic energy of the car.
4. A force of magnitude 5N acts on a 2kg body moving initially in the direction of the force with a speed of 4m/s. Over what distance must the force act in order to change the body's speed to 6m/s?
5. A 50N force is applied horizontally to 10kg block which is initially at rest. After traveling 8m, the speed of the block is 5m/s. What is the coefficient of kinetic fraction?

4.3. Potential Energy and Conservation of Energy

In this section we will discuss another form of mechanical energy, called ***potential energy***, associated with the position or configuration (arrangement) of object. Thus, the potential energy of a system of interacting objects represents the ability of the system to do work because of its position or configuration.

Potential energy is present in the Universe in various forms, including gravitational, elastic, electromagnetic, chemical, and nuclear. Furthermore, one form of energy in a system can be converted to another. For example, when a system consists of an electric motor connected to a battery, the chemical energy in the battery is converted to kinetic energy as the shaft of the motor turns. The transformation of energy from one form to another is an essential part of the study of physics, engineering, chemistry, biology, geology, and astronomy.

4.3.1. Gravitational potential energy

Gravitational potential energy U is the energy associated with the state of separation between two objects that attract each other by the gr consider a physics book of mass m lifted from an initial height y_i to a final height above the surface of the earth, as indicated in Fig. 4.3.1

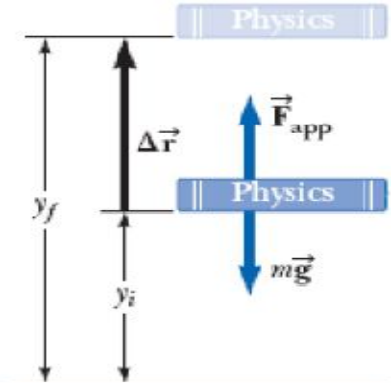


Fig. 4.3.1A physics book lifted up

The work done by gravitational force as the book is raised height y_f from the ground is given by

$$Wg=|\boldsymbol{F}g||\Delta\boldsymbol{r}|\cos\theta,$$

where $\boldsymbol{F}g=-mg\hat{\jmath}$ is the gravitational force on the book and $\Delta\boldsymbol{r}=(y_f-y_i)\hat{\jmath}$ is the displacement and θ is the angle between the gravitational force and the displacement. In Figure ,θ=180°. It then follows that

$$Wg=-[mgy_f-mgy_i].$$

The quantity $Ug=mgy$ is called gravitational potential energy. Thus $Ug_f=mgy_f$ is the final gravitational potential energy and $Ugi=mgy_i$ is the initial gravitational potential energy of the earth-book system. Accordingly, the work done by gravitational force can be expressed as

$$Wg=-[Ug_f-Ug_i]=-\Delta Ug.$$

We observe that work done by gravitational force is equal to the negative of the change in gravitational potential energy. When the object moves down y decreases, the gravitational force does *positive* work, and the potential energy *decreases.* When the object moves *up*, the work done by the gravitational force is *negative,* and the potential energy *increases.*

It is often convenient to choose as the reference configuration for zero potential energy the configuration in which an object is at the surface of the Earth, but this is not essential.

Example 1: A 2kg book is placed on a shelf 2.5m height above the ground. What is the Gravitational potential energy of the book?

Ug= mgh

Ug= (2kg)(10m/s^2)(2.5m)

=<u>50J</u>

Example 2: A 1kg apple is falling down freely through a distance of 1.5m from the top of the tree.

a) What is loss in Gravitational Potential Energy of the apple?

b) Where does it go the loss in GPE?

Solution

a) The loss in GPE=ΔUg =mgy

=1kgx10m/s2x1.5m

=<u>30J</u>

b) It changes into kinetic energy

Review Questions

1. A boy, of mass 30 kg, climbs onto the roof of their garage. The roof is 2.5 m from the ground. He now jumps off the roof and lands on the ground.

(a) How much potential energy has the boy gained by climbing on the roof?

(b) He now jumps down. What is his potential energy when he is 1 m from the ground?

(c) What is the potential energy of the boy when he lands on the ground?

2. A 60kg hiker walks up a mountain, 800 m above sea level, to spend the night at the top in the first overnight hut. The second day he walks to the second overnight hut, 500 m above sea level. The third day he returns to his starting point, 200m above sea level.

(a) What is the potential energy of the hiker at the first hut (relative to sea level)?

(b) How much potential energy has the hiker lost during the second day?

(c) How much potential energy did the hiker have when he started his journey(relative to sea level)?

(d) How much potential energy did the hiker have at the end of his journey?

4.3. 2. Elastic potential energy

We are familiar now with gravitational potential energy; let us explore a second type of potential energy. When a spring is stretched (or compressed) from its equilibrium position, it has ability to do work as it returns to the equilibrium position. Thus, the spring may have the potential for doing work because of its stretch (or compression). Energy that is stored in an elastic object when you stretch, compress, twist, or otherwise deform it is called elastic potential energy. Consider an object of mass ***m*** attached to a spring of spring constant ***k***, as shown in Fig.4.3.2

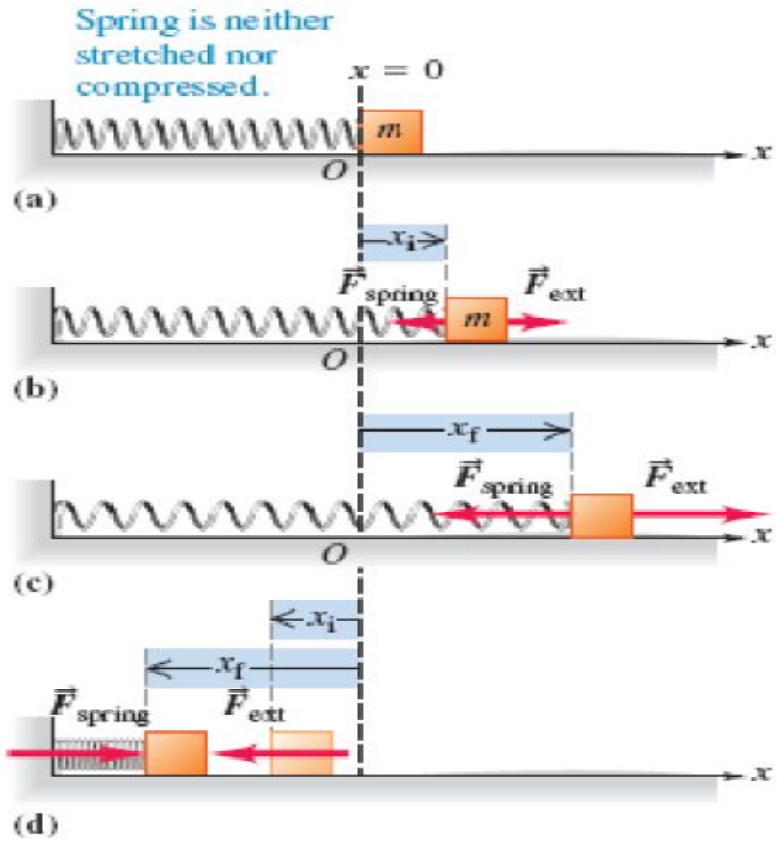


Fig. 4.3.2 A block attached to a spring and acted upon by a force

For a force that is a linear function of position, such as spring force (F_{sp}=$-kx$), the work done by the force is the average force multiplied by the displacement. Accordingly, the work done by spring force when the spring is stretched from x_i to x_f is the product of the average spring force and the displacement. That is;

$$W_{sp} = -\frac{1}{2}k(x_f + x_i)(x_f - x_i) = -\frac{1}{2}k({x^2}_f - {x^2}_i)$$

The quantity $U_{elas} = \frac{1}{2}kx^2$ is elastic potential energy of spring-mass system when the spring is stretched or compressed by x. We thus notice that $U_{elas\,f} = \frac{1}{2}kx_f^2$ is the final elastic potential energy and $U_{elas\,i} = \frac{1}{2}kx_i^2$ is the initial elastic potential energy. Accordingly, we observe from the above equation that the work done by spring force when the spring is stretched from x_i to x_f is equal to the negative of the change in elastic potential energy. That is,

$$W_{sp} = -(U_{elaf} - U_{elai}) = -\Delta U_{ela}.$$

Example 1: Calculate the energy stored in a spring when it is stretched 8cm by a 100N force?

Solution:

$F=kx$ and $F_{av}=1/2(kx)=1/2x100N=50N$

$W=(F_{av})(x)=50Nx0.08m=4J$

Example 2: A spring with a spring constant of 1500N/m is compressed by 5cm. How much elastic potential energy will be stored in the spring?

Solution:

$k=1500N/m$, $x=5cm=5x10^{-2}m$

$Us=?$

$Us=\frac{1}{2}kx^2$

$=\frac{1}{2}(1500N/m)(5x10^{-2}m)^2$

$=1.875J$

4.3.3 The Isolated System–Conservation of Mechanical Energy

The introduction of potential energy allows us to generate a powerful and universally applicable principle for solving problems that are difficult to solve with Newton's laws. Let us develop this new principle by thinking about the book–Earth system in the Figure again

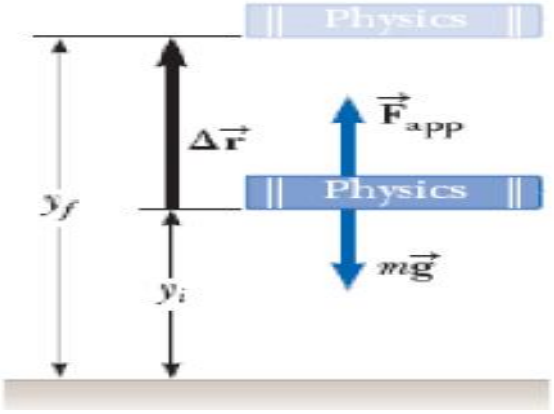


Figure 4.3.3 Conservation of Mechanical Energy

After we have lifted the book, there is gravitational potential energy stored in the system, which we can calculate from the work done by the external agent on the system, using $W=\Delta Ug$.

Let us now shift our focus to the work done on the book alone by the gravitational force (Figure) as the book falls back to its original height. As the book falls from y_f to y_i, the work done by the gravitational force on the book is

$$W_{\text{on book}}=|\boldsymbol{F}_g||\Delta\boldsymbol{r}|\cos\theta=-[mgy_i-mgy_f]=mgy_f-mgy_i$$

From the work–kinetic energy theorem, the work done on the book is equal to the change in the kinetic energy of the book:

$$W_{\text{on book}}=\Delta K_{\text{book}}$$

Therefore, equating these two expressions for the work done on the book,

$$\Delta K_{\text{book}}=mgy_f-mgy_i$$

Now, let us relate each side of this equation to the *system* of the book and the Earth. For the right-hand side,

$$mgy_f-mgy_i=-[mgy_i-mgy_f]=-(Uf-U_i)=-\Delta U_g$$

where *Ug* is the gravitational potential energy of the system. For the left-hand side of the Equation, because the book is the only part of the system that is moving, we see that $\Delta K_{book}=\Delta K$, where *K* is the kinetic energy of the system. Thus, with each side of the Equation replaced with its system equivalent, the equation becomes

$$\Delta K=-\Delta U_g$$

This equation can be manipulated to provide a very important general result for solving problems. First, we bring the change in potential energy to the left side of the equation:

$$\Delta K+\Delta U_g=0$$

On the left, we have a sum of changes of the energy stored in the system. The right hand is zero because there are no transfers of energy across the boundary of the system—the book–Earth system is *isolated* from the environment.

We define the sum of kinetic and potential energies as ***mechanical energy***:

$$E_{mech}+K+Ug$$

We will encounter other types of potential energy besides gravitational later in the text, so we can write the general form of the definition for mechanical energy without a subscripton *U*:

$$E_{mech}=K+U$$

where *U* represents the total of *all* types of potential energy.

Let us now write the changes in energy explicitly:

$$(K_f-K_i)+(U_f-U_i)=0$$

$$K_f+U_f=K_i+U_i$$

For the gravitational situation that we have described, one can written as

$$\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + mgy_i$$

As the book falls to the Earth, the book–Earth system loses potential energy and gains kinetic energy, such that the total of the two types of energy always remains constant.

The above Equation is a statement of ***conservation of mechanical energy for an isolated system***. An isolated system is one for which there are no energy transfers across the boundary. The energy in such a system is conserved—the sum of the kinetic and potential energies remains constant. (This statement assumes that no *nonconservative forces* act within the system; such as frictional force)

Example 1: A bird of 5000g is flying at a speed of 20m/s at an altitude of 600m above the ground. Determine the mechanical energy of this bird?

Mechanical energy = $\sum Potentia\ Energy + \sum Kinetic\ Energy$

ME= PE + KE

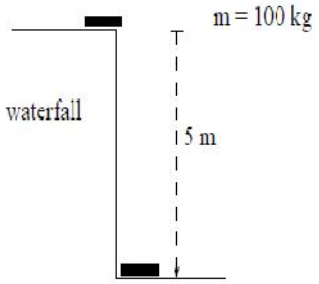
$K=\frac{1}{2}mv^2=\frac{1}{2}(5kg)(20m/s)^2=1000J$ and Ug= mgh =5kgx10m/s^{2}x600m =30000J

E_{mech}= 30000J + 1000J =31000J

Example 2: During a flood a tree truck of mass 100 kg falls down a waterfall. The waterfall is 5 m high. If air resistance is ignored, calculate

a. the potential energy of the tree trunk at the top of the waterfall.
b. the kinetic energy of the tree trunk at the bottom of the waterfall.
c. the magnitude of the velocity of the tree trunk at the bottom of the waterfall.

m=100kg h=5m



a) Ug=?

Ug=mgh

=100KgX10m/sX5m=5000J

b) Using conservation of mechanical energy

$E_{bottom} = E_{top}$

At the top the energy is purely potential and at the bottom the energy is purely kinetic. Thus

K=Ug=mgh=5000J

c) Using the expression for kinetic energy

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

$v = \sqrt{2gh}$=10m/s

Conservative and Non-conservative (Dissipative) Forces

Conservative Forces

Conservative forces have these two equivalent properties:

1. The work done by a conservative force on a particle moving between any two pointsis independent of the path taken by the particle.

2. The work done by a conservative force on a particle moving through any closed path is zero. (A closed path is one in which the beginning and end points are identical.)The gravitational force is one example of a conservative force, and the force that a spring exerts on any object attached to the spring is another.

In general, the work *Wc* done by a conservative force on an object that is a member of a system as the object moves from one position to another is equal to the initial value of the potential energy of the system minus the final value:

$$W_C = U_f - U_i = -\Delta U$$

Nonconservative Forces

A force is non-conservative if it does not satisfy properties 1 and 2 for conservative forces. Non-conservative forces acting within a system cause a *change* in the mechanical energy *E* of the system.

Energy in oscillating systems

We have seen that when an object falls its GPE is converted into kinetic energy. The same is true if you throw an object into the air. Here the kinetic energy is transformed into GPE as it rises.

In oscillating systems kinetic energy is continuously being transformed into potential energy and vice-versa. If there are no energy losses, then the total mechanical energy will remain constant forever.

Consider the following examples

A) The oscillation of Simple pendulum

In oscillation of simple pendulum, in the absence of friction, the mechanical energy is conserved when the bob swings between A and B. The two points are called amplitude position.

Point C refers to the equilibrium position of the bob.

<u>At amplitude positions(at A and B)</u>

$KE_A=KE_B=0$

$GPE_A=GPE_B=mgh$

$ME_A= KE_A+ GPE_A=mgh$

$ME_B=KE_B + GPE_B=mgh$

$ME_A= ME_B=mgh$

<u>At equilibrium positions(at C)</u>

$KE_C=\frac{1}{2}mv_c^2$

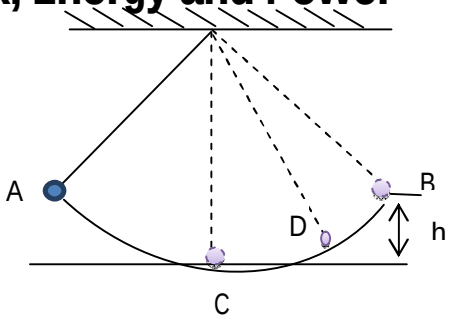
$GPE_c= 0$

$ME_A= KE_A+ GPE_A=mgh$

$ME_B=KE_B + GPE_B=mgh$

$ME_c= KE_B+ GPE_B=\frac{1}{2}mv_c^2$

<u>At positions D</u>



4. 3.4 A simple pendulum transforms GPE into K.E and then back again.

Position D is any position on the curve between C and B or C and A. At this position both Kinetic energy and potential energy are existed.

$KE_D =\frac{1}{2}mv_c^2$

$GPE_D= mgh_D$

The mechanical energy at any position is conserved. Therefore, the mechanical energy at each position is the same.

$ME_A=ME_B=ME_C=ME_D$

$mgh=\frac{1}{2}mv_c^2 =\frac{1}{2}mv_D^2 + mgh_D$

$ME_A= KE_A+ GPE_A=mgh$

$ME_B=KE_B + GPE_B=mgh$

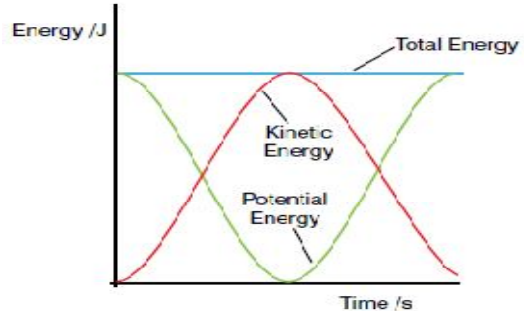
$ME_c= KE_B+ GPE_B=\frac{1}{2}mv_c^2$

$ME_D= KE_D + GPE_D$

$=\frac{1}{2}mv_D^2 + mgh_D$

The total mechanical energy = kinetic energy + potential energy

Another example of an oscillating system is a mass–spring system. In simple terms this is just a mass on the end of a spring. However, the suspension in a car is a more complex example of a mass–spring system. In this case the potential energy may not be GPE, instead it may be EPE.



4.3.5 Graph showing how the potential energy and kinetic energy of oscillating systems are related

As the spring is compressed the EPE increases and the mass slows down (its *Ek* decreases). Eventually the mass will stop; at this point the EPE is at its maximum and the *Ek*is zero. The mass then accelerates as EPE is converted into *Ek*. This process continues.

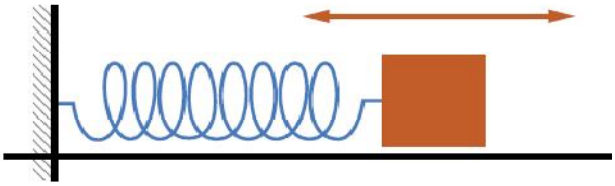


Fig. 4.3.6 An example of a mass–spring system

A more complex example might be a mass–spring system oscillating vertically like the one shown in Figure 4.3.5In this case the kinetic energy is changed into GPE and EPE. In any case the total mechanical energy of the system remains the same.

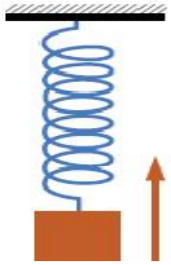


Fig. 4.3.7 A vertically oscillating mass–spring system

Energy resources

Every country demands a huge amount of energy, from fuel to run cars and other vehicles, to gas for cooking and heating and, of course, electrical energy. A source of energy that may be used by a country or individuals within that country is commonly referred to as an **energy resource**. Examples of energy resources are Oil, Fuel, Nuclear, Natural gas, Solar, Geothermal …etc

Energy resources are very precious commodities, perhaps the most obvious being oil.

Selecting which energy resources to use is often a very difficult decision. There are lots of factors to consider, chief among them being the availability of the resource, the economics involved and the subsequent environmental impact (more on this later).

We can't use each directly as it is. We need a suitable device to convert the naturally existing energy resources into useful forms of energy.

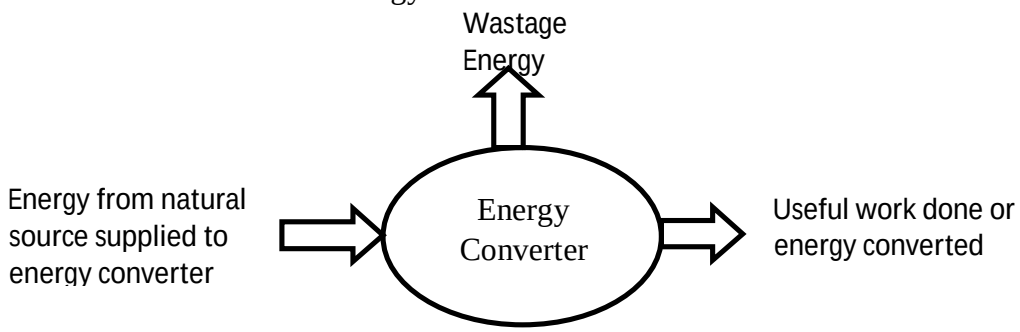


Fig. 4.3.8 Energy converter

Wind mill, Hydroelectric power generator, solar power …etc are examples of energy convertors.

Energy resources are often used to generate electricity. Electricity is exceptionally useful as it is quite simple to transfer a vast amount of energy from one place to another (all you need is a suitable wire!) and it can be easily transformed into most other forms of energy.

Most methods of electricity generation involve a rotating turbine. This turbine turns a generator (a magnet or series of magnets inside coils of wire).This generator converts kinetic energy into electrical energy.



Fig. 4.3.9 A simple generator

Globally the most common method for generating electricity involves the burning of **fossil fuels** such as coal, oil and natural gas. The chemical energy contained within these fuels is released as heat(through burning), this heat is used to turn water into steam, this steam then turns a turbine to generate electricity.

Large fossil fuel power stations can generate up to 4 billion joules per second! However, such a global reliance on fossil fuels is problematic for two main reasons.



Fig.4.3.10 An example of a coal-fired power station

- Fossil fuels are a finite energy resource. Eventually we will run out of coal, oil and natural gas.
- Burning fossil fuels produces several atmospheric pollutants, including sulphur dioxide and perhaps more worryingly, carbon dioxide. Carbon dioxide (CO2) is a powerful greenhouse gas. It is thought the increase in CO2 output is a significant factor in manmade global warming, heating up the entire planet and leading to dramatic changes to weather and climate.

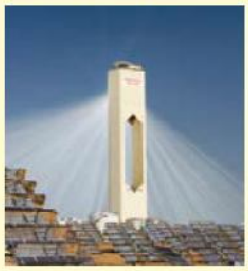
Ethiopia has few proven fossil fuel resources. However, some people estimate that there is considerable potential for oil and natural gas exploration in the future. In a nuclear power station uranium is used as a fuel. Inside the reactor there is a complex nuclear reaction (fission – splitting the atom). This process generates heat, which is used to turn water to steam, etc. The only real difference between a nuclear power station and a coal-fired one is the method for generating the heat. In a nuclear reactor a great deal of heat can be produced per kg of uranium, and so nuclear plants can generate vast amounts of electricity. As no fuel is 'burnt' there are no greenhouse gases produced; however, this process produces radioactive waste. This waste will remain dangerous for millions of years.

Renewable and non-renewable energy resources

Resources that do not involve a fuel that will eventually run out are referred to as **renewable**. Table 4.3.1 includes a selection of some of the forms of renewable energy resources. This is not a definitive list; other forms include tidal (energy from tidal movements), wave(energy from water waves) and biomass (burning organic matter specifically grown for the task).

Table 4.3.1 Comparison of some renewable energy resources

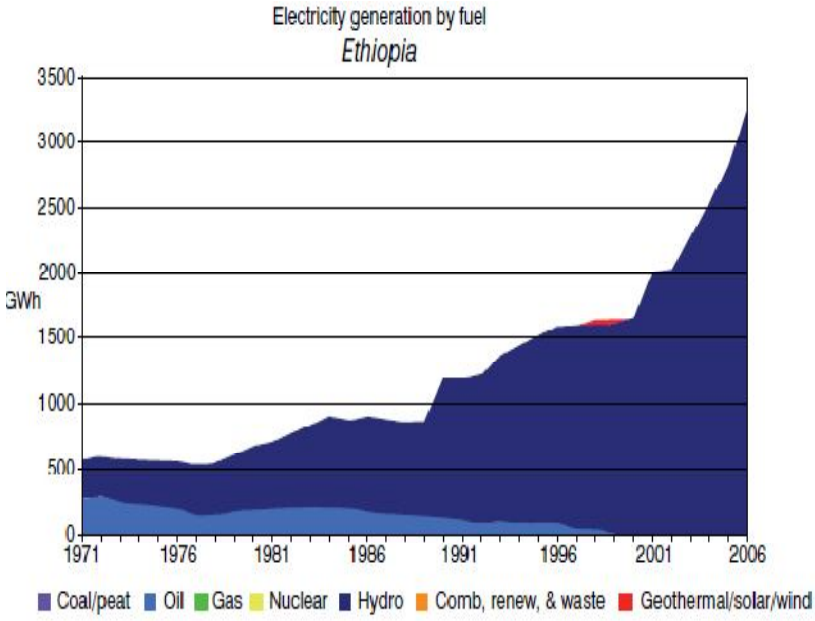
Type	Description	Positives	Negatives
Wind 	The Sun heats the Earth's surface. This heating is uneven and so creates convection currents. This leads to areas of higher and lower pressure and wind moves between them. The wind turns large turbines and this generates electricity.	Relatively inexpensive – just running costs. Does not produce any greenhouse gases.	Not a consistent supply. When there is no wind there is no electricity generated. A large number of turbines are needed to generate a significant amount of power.
Geothermal 	Heat from processes inside the Earth is used to turn water into steam. Water is pumped down into 'hotspots' in the Earth's crust. It is turned to steam and this steam is used to turn turbines to generate electricity.	Only small amount of greenhouse gases are released (due to gases trapped inside the Earth being released in the process). Can generate a significant amount of power.	Only certain locations are suitable for geothermal power plants (see next section). Initial construction can be expensive.
Hydroelectric 	Falling water turns turbines to generate electricity. In order to provide a sufficient drop in height large dams are often constructed. The water builds up behind the dam and is then released through turbines.	Only a small amount of greenhouse house gases are produced. Very large amounts of energy can be generated with relatively small running costs. Hydroelectric plants tend to have longer lives than thermal power stations.	Construction of large dams can damage the local environment. This may affect a significant number of the local inhabitants (animal and human). Initial construction can be very expensive and is limited to only certain sites. Generation may be affected by extended droughts.
Solar (photovoltaic) 	The first type of solar power converts the energy in sunlight directly into electrical energy (via photovoltaic cells).	No greenhouse gases. Very low running costs.	Construction often involves the use of a large quantity of toxic materials. Photovoltaic cells remain very expensive. Only a relatively small amount of energy is generated per km^2.

Type	Description	Positives	Negatives
Solar (concentrating solar power) 	The second type of solar power involves using carefully aligned mirrors to focus the sunlight onto a boiler. The heat turns water to steam and this turns a turbine.	Generates more energy per km² than photovoltaics. No greenhouse gases are produced.	Mirrors need to be very carefully aligned. Sophisticated technology is needed to ensure they track the Sun as it moves across the sky.

In 2020 as a country we generated just over 6×10^{16} J (10,000,000,000,000,000 J!!) of electrical energy. At the time of writing around nearly all of our electricity generation comes from hydroelectric power.



4.3.11 The location of hydroelectric power plants



*4.3.12.*This graph shows the amount of electricity generated per resource.

As part of the country's general development plan, with the aim of expanding the Electric Power generation capacity, Gilgel Gibe III, Tekeze, Genale-Dawa (GD-3), Gilgel Gibe II and Tana Beles power plants with respective generating capacities of 1870MW, 300MW, 254MW, 184MW and 460MW became operational from 2009 and 2020. The Grand Ethiopian Renaissance Dam (GERD) that has a generating capacity of over 6000MW will be operational in the near future. Reliance on hydroelectric power has advantages and disadvantages, as listed in Table 4.3.1 Ethiopia can diversify its electricity sources by exploiting its geothermal (> 9000 MW) and wind (>10 000MW) electricity generating Potential. Figure 4.3.11 shows the location of several hydroelectric power plants. Ethiopia is among only a few African countries with the potential for significant energy generation to come from geothermal wind power.

Non-renewable energy resources

Fossil fuels such as Coal, gas and oil are energy sources which are results of ancient remains of plants and animals. The energy from such supplies is used by burning then. Once you burn them the energy is used up forever. You cannot replace the energy from such sources. The sources which give energy that cannot be replaced are known as non-renewable energy sources.
Nuclear energy is also another form of non-renewable energy source which developed nations use to generate electricity. The world has a tendency of replacing non-renewable energy sources by renewable sources.

4.4. Power

Consider Conceptual Example, which involved rolling a refrigerator up a ramp into a truck. Suppose that the man is not convinced by our argument that the work is the same regardless of the length of the ramp and sets up a long ramp with a gentle rise. Although he will do the same amount of work as someone using a shorter ramp, he will take longer to do the work simply because he has to move the refrigerator over a greater distance. While the work done on both ramps is the same, there is ***something*** different about the tasks—the ***time interval*** during which the work is done.

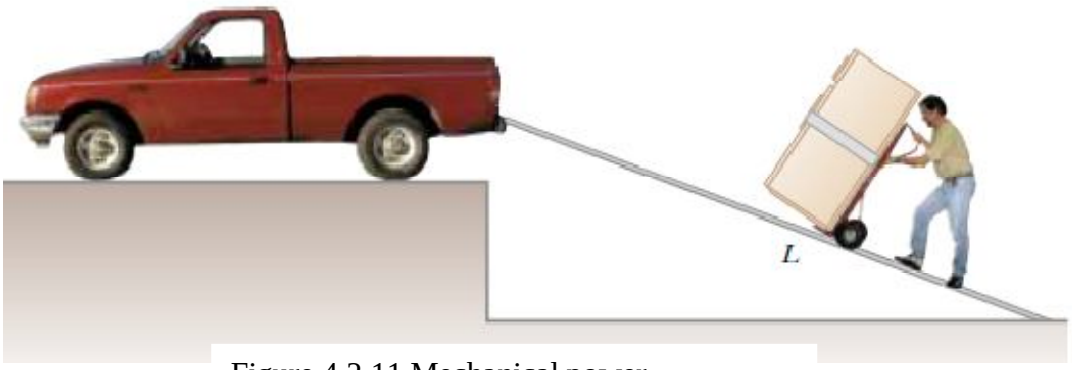


Figure 4.2.11 Mechanical power

method in this discussion, but keep in mind that the notion of power is valid for *any* means of energy transfer. If an external force is applied to an object (which we assume acts as a particle), and if the work done by this force in the time intervalΔt is W, then the **average power** during this interval is defined as

$$p_{average} = \frac{Work\ done}{time\ interval}$$

$$p_{average} = \frac{W}{\Delta t}$$

Thus, while the same work is done in rolling the refrigerator up both ramps, less poweris required for the longer ramp.

Power in terms of Force and Velocity

We already know that power is the time rate of Work done. So, during time interval Δt the average power can be defined as:

$$P_{av}=\frac{\Delta W}{\Delta t}$$

ΔW is the work done in the time period of Δt. Since, we know that W = F.S and if F is constant, we can rewrite the above equation as:

$$P_{av}=F.\frac{\Delta S}{\Delta t}$$

Here, F is the force, ΔS is the displacement of the object and Δt is the time period of that displacement. Since, we know that v_{ava}= ΔS/Δt is the average velocity of the object, we can rewrite the above equation as:

$$P_{av}=Fv_{ave}$$

In a manner similar to the way we approached the definition of velocity and acceleration, we define the instantaneous power p as the limiting value of the average power as Δt approaches zero:

$$P = \lim_{\Delta t\to o}\frac{W}{\Delta t} = \boldsymbol{F}.\lim_{\Delta t\to o}\frac{\Delta \boldsymbol{x}}{\Delta t} = \boldsymbol{F}.\boldsymbol{v}=Fv\cos\theta\ ,$$

where F is the force at that instant of time and θ is the angle between **F** and **V** vectors.
For steady velocity, v_{ave}=v and constant force F, then we can express the power in terms of force and velocity as

$$P=Fv$$

$$P = Fv\cos\theta$$

When a body accelerates uniformly from V_i to V_f, the average velocity can be taken as

$v_{ave}=\frac{v_{f+}\, v_i}{2}$ for a constant force the average power is

$$P_{av}=Fv_{ave}$$

In general, power is defined for any type of energy transfer. Power is the rate at which energy is crossing the boundary of the system by a given transfer mechanism.
The SI unit of power is joules per second (J/s), also called the watt (W) (after James Watt):
Another unit of power is the horsepower (hp):

1 hp = 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 h at the constant rate of1 kW =1 000 J/s.
The amount of energy represented by 1 kWh is

$$1 \text{ kWh} = (10^3 \text{W})(3600 \text{ s}) = 3.60 \text{ X } 10^6 \text{ J}$$

Note that a kilowatt-hour is a unit of energy, not power. When you pay your electric bill, you are buying energy, and the amount of energy transferred by electrical transmission into a home during the period represented by the electric bill is usually expressed in kilowatt-hours.

Example 1:

a) How much work is done by a 500 W motor running for 30 minutes?

In joules:

$$\mathbf{W = P\,t}$$

In this case the time taken is 30 minutes, which is 1800 s, and P =500 W.

W = 500 W X1800 s

W = 900 000 J or 900 kJ

In kilowatt-hours:

$W = P\,t$

In this case the time taken is 30 minutes, which is 0.5 hours, and P= 500 W, which is 0.5 kW.

W = 0.5 kWX0.5 h

W = 0.25 kWh

Example 2: Calculate the power required for a force of 10 N applied to move a 10 kg box at a speed of 1 m/s over a frictionless surface.

Solution:

F=10N and V=1m/s

We can therefore calculate power from:

$P = \mathbf{F} \cdot \mathbf{v}$

= (10N)(1m/s)

= 10W

Summery

A system is most often a single particle, a collection of particles or a region of space. A system boundary separates the system from the environment. Many physics problems can be solved by considering the interaction of a system with its environment.

The work W done on a system by an agent exerting a constant force F on the system is the product of the magnitude $\Delta x$of the displacement of the point of application of the force and the component $F\cos\theta$ of the force along the direction of the displacementΔx:

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

Frictional force always does negative work. Its effect is always to decrease the energy of the body on which it is doing work.

$$W_{\text{against friction}} = f_{\text{kinetic}}\, s = \mu_{\text{kinetic}}\, s\, N$$

The kinetic energy of a particle of mass m moving with a speed v is

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

The work–kinetic energy theorem states that if work is done on a system by externalforces and the only change in the system is in its speed, then

$$W_{net} = KE_f - KE_i$$

If a particle of mass *m* is at a distance *y* above the Earth's surface, the gravitational potential energy of the particle–Earth system is

$$Ug = mgy$$

The elastic potential energy stored in a spring of force constant *k* is

$$U_{elas} = \frac{1}{2}Kx^2$$

A reference configuration of the system should be chosen, and this configuration is often assigned a potential energy of zero.

A force is conservative if the work it does on a particle moving between two points is independent of the path the particle takes between the two points. Furthermore, a force is conservative if the work it does on a particle is zero when the particle moves through an arbitrary closed path and returns to its initial position. A force that does not meet these criteria is said to be nonconservative.

The total mechanical energy of a system is defined as the sum of the kinetic energy and the potential energy:

$$E_{\text{mech}} = K + U$$

If a system is isolated and if no nonconservative forces are acting on objects inside the system, then the total mechanical energy of the system is constant:

$$K_f + U_f = K_i + U_i$$

If nonconservative forces (such as friction) act on objects inside a system, then mechanical energy is not conserved. In these situations, the difference between the total final mechanical energy and the total initial mechanical energy of the system equals the energy transformed to internal energy by the nonconservative forces.

The **average power** during this interval is defined as

$$p_{average} = \frac{Work\ done}{time\ interval} = \frac{W}{\Delta t}$$

The instantaneous power P is defined as the time rate of energy transfer. If an agent applies a force F to an object moving with a velocity v, the power delivered by that agent is

$$\mathbf{P = F.V}$$

End of unit Questions and problems

Questions

1. Cite two examples in which a force is exerted on an object without doing any work on the object.
2. One bullet has twice the mass of a second bullet. If both are fired so that they have the same speed, which has more kinetic energy? What is the ratio of the kinetic energies of the two bullets?
3. (a) If the speed of a particle is doubled, what happens toits kinetic energy? (b) What can be said about the speed ofa particle if the net work done on it is zero?
4. An elevator is pulled by its cables at constant speed. Is the total work done on the elevator positive, negative or zero?
5. Explain why the total energy of a system can be either positive or negative, whereas the kinetic energy is always positive.
6. Are there any cases where a frictional force can increase the mechanical energy of a system? If so give examples.
7. If only one external force acts on a particle, does it necessarily change the particle's (a) kinetic energy? (b) velocity?
8. Discuss the changes in mechanical energy of an object–Earth system in (a) lifting the object, (b) holding the object at a fixed position, and (c) lowering the object slowly. Include the muscles in your discussion.
9. Can the average power over a time interval ever be equal to the instantaneous power at an instant within the interval? Explain.
10. As a simple pendulum swings back and forth, the forces acting on the suspended object are the gravitational force, the tension in the supporting cord, and air resistance.

(a) Which of these forces, if any, does no work on the pendulum?
(b) Which of these forces does negative work at all times during its motion?
(c) Describe the work done by the gravitational force while the pendulum is swinging.

Problems

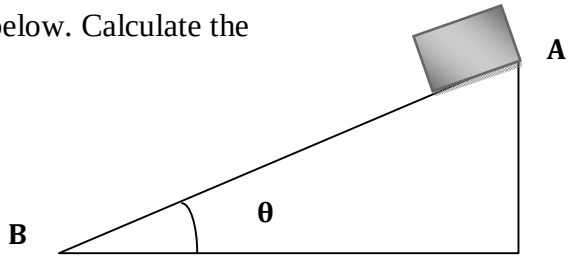
1) How much energy is stored on a 2000N/m spring when it is compressed by a 4cm?
2) By what amount will it be stretched in order to store a 5.4J of energy on a 1500N/m spring?
3. Suppose a student stretches a spring with a spring constant of 1600N/ in increasing the force applied uniformly from 0 to 80N. a) How much energy does he store in the spring?
b) How much work is done on the spring? c) How much work is done by the spring?
4. a) Calculate the energy stored in a spring when it is compressed 8mm by an average force of 120N? b) What is the spring constant of the spring?

5) A 1000kg car starting from rest accelerates uniformly through a distance of 800m along a straight road. The net force causing this acceleration is 810N. Determine the final speed of the car.

6) A boy kicks a ball of mass 80g and the ball leaves his foot with a velocity of 20m/s. What is the kinetic energy of the ball just when it left the foot of the boy?

7) A student uses a catapult to shoot a stone of mass 30g by stretching its rubber and storing an elastic potential energy of 6J. If all the EPE is converted into kinetic, with what speed will the stone leave the Catapult?

8. A box of mass 6kg starts from rest at **A** and slides down a rough slope length 10m which makes anangle of 37^0above the horizontal as shown below. Calculate the



a) work done on the box by the gravitational force

b) change in kinetic energy of the box

c) work done by the net force

d) magnitude of the frictional force acting on the box

e) speed of the box at the bottom of the plane.

9. A 50kg crate is pulled across a horizontal floor at a constant velocity with a force "F" at 37^0 above the horizontal.

A 24N frictional force opposes the motion of the crate as it moves through a distance of 5m.

i) What is the work done on the crate by the a) applied force b) frictional force c) gravitational force d) normal force ii) what os the total work done on the crate

10. A 0.09kg arrow is fired horizontally. The bowstring exerts an average force of 80N on the arrow over a distance of 0.9m. With what speed does the arrow leave the bow?

11. Hailue and Negasa are running with the same speed but Hailu has 3times the mass as Negasa. If Hailu has a kinetic energy of 420J, what will be the kinetic energy of Negasa?

12. Two identical baseballs A and B are hit by the same batter but ball A has 5times the velocity as ball B. If ball B has a kinetic energy of 1.2x103J, what is the kinetic of ball A?

13.If five a 60W and two a 100W electric lamps are operating for 5hours per a day, how much electric energy is consumed by the lamps per a month?

14. A body has a kinetic energy of 840J. What will be the new kinetic energy of the body if its speed is

i) doubled? ii) reduced to one fourth of its initial value?

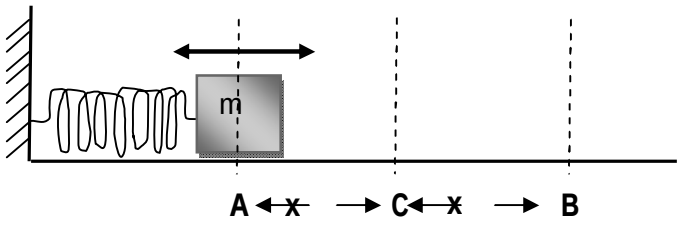
15. A block falling through the air by 60m does a work equal to -7200J. What is the mass of the block?

16. A crane lifts a 400kg load vertically to a height of 10m from the ground in 5seconds. What is the power developed by the crane?

17.A boy shoots a 0.04kg stone using a catapult by stretching its rubber to 0.4m with an average force of 20N. What will be the speed of the stone as it leaves the Catapult?

18. A car travel at 15m/s against a force of friction of 5600N between its fire and the road. What is the power developed by the engine of the car?

19. In a mass-spring oscillating system, the 2kg mass on the free end of the spring oscillates freely back and forth b/n the two amplitude positions **A** and **B** as shown below. Given that x=4cm.



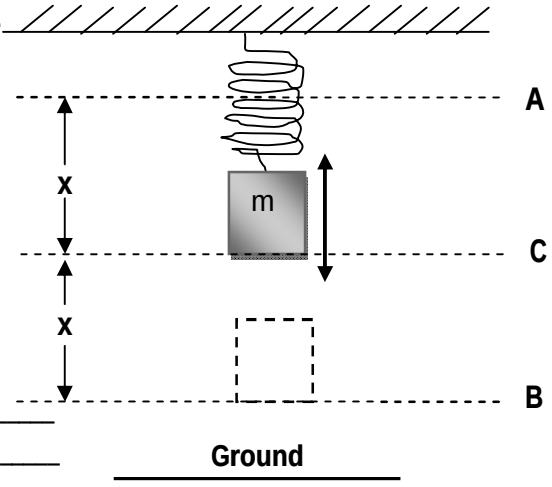
i) Calculate the mechanical energy at

a) the amplitude positions. b) the equilibrium position.

C) a distance of 2cm from the equilibrium position.

ii) Calculate the speed of the mass at a distance of 2cm from the equilibrium position.

20. In a vertical mass-spring oscillating system, the 2kg mass on the free end of the spring oscillates freely up and down b/n the two amplitude positions **A** and **B** as shown below. Given that x=4cm and the spring constant 2000N/m.



i) At position A or B, calculate the

KE_A=_____

GPE_A=_____

EPE_A= _____

ME_A= _____

V_A= _____

ii) At the equilibrium position, calculate

KE_C=_____ GPE_C=_____

EPE_C= _____ ME_C= _____

V_c= _____

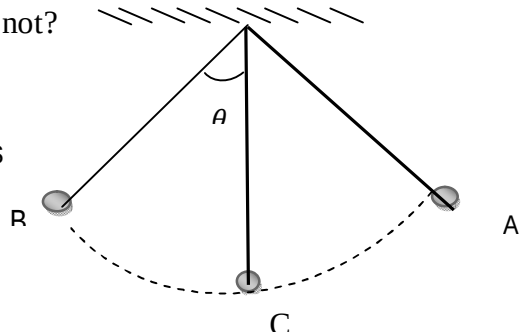
21. A bullet, mass 50 g, is shot vertically up in the air with a muzzle velocity of $200 m \cdot s^{-1}$. Use the Principle of Conservation of Mechanical Energy to determine the height that the bullet will reach. Ignore air friction.

22. A skier, mass 50 kg, is at the top of a 6.4 m ski slope.

(a) Determine the maximum velocity that she can reach when she skies to the bottom of the slope

(b) Do you think that she will reach this velocity? Why/Why not?

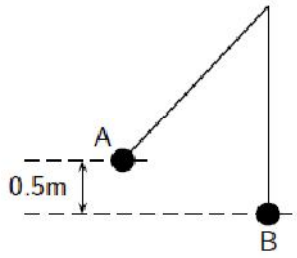
23. In the oscillation of simple pendulum, there is a transformation of energy from one form to another form. What will be the transformation of energy when the mass moves from:-



a) C to A? b) C to B?

c) A to C? d) B to C?

24. A 2 kg metal ball is suspended from a rope. If it is released from point A and swings down to the point B (the bottom of its arc):



(a) Show that the velocity of the ball is independent of it mass.

(b) Calculate the velocity of the ball at point B.

25. A tennis ball, of mass 120 g, is dropped from a height of 5 m. Ignore air friction.

(a) What is the potential energy of the ball when it has fallen 3 m?

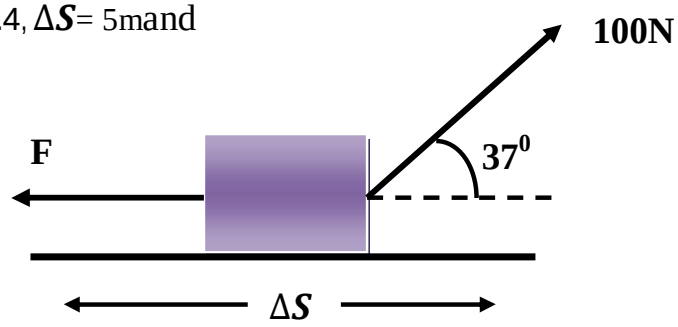
(b) What is the velocity of the ball when it hits the ground?

26. A pendulum bob of mass 1.5 kg, swings from a height A to the bottom of its arc at B. The velocity of the bob at B is 4 $m \cdot s^{-1}$. Calculate the height A from which the bob was released. Ignore the effects of air friction.

27. In the diagram below, calculate the work done by the applied force, the frictional force, the normal force and by the net force if $\mu_k = 0.4$, $\Delta S = 5$m and

a) F= 40N

b) F= 130N



28. What power is required to pull a 5kg block at a steady speed of 2m/s? The coefficient of friction is 0.3.

29. Determine the work done by each of the following force.

a) F= (8 , 0)N and ΔS =(5, 0) m

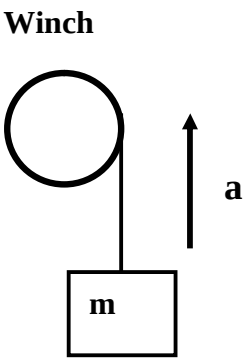
b) F= (0 ,12)N and ΔS =(0, 10) m

c) F= (8, 6) N and ΔS =(3, 4) m

30. A Winch lifts a 150kg crate 3m upwards with acceleration of $2m/s^2$.

a) How much work is done by the Winch?

b) How much work is done by the gravity?



31. A 7500W engine is propelling a boat at 72km/h.

What force is the engine exerting on the boat?