SPH4U UNIVERSITY PHYSICS

ENERGY & MOMENTUM

- Work
  (P.164-170)

Work

*In everyday language, the term "work" has a variety of meanings. In physics, however, **work** is the energy transferred to an object when a force acting on the object moves it through a distance. For example, to raise your backpack from the floor to your desk, you must do work. The work you do in raising the backpack is directly proportional to the magnitude of both the displacement and the applied force (i.e. W=Fd).*

October 8, 2012 4U2 - Work 1

Work

WORK

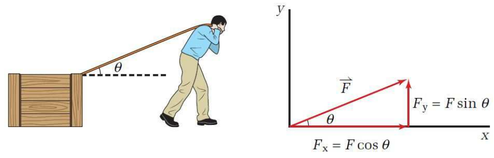
- the energy transferred to an object when a force acting on the object moves it through a distance
- is a scalar quantity

October 8, 2012 4U2 - Work 2

Work

NOTE!

In the previous example, the force needed to raise the backpack and the displacement of the backpack were in the same direction. However, this is often not the case. Consider the situation where the force is at some angle θ to the displacement. The component of the force that is parallel to the displacement, Fcosθ, causes the objet to undergo the displacement. In this case, W=(Fcosθ)Δd.



Work

WORK (W)

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

where W is the work done (J) ☞ 1 J = 1 N·m = 1 kg·m^2/s^2

F is the applied force (N)

Δd is the displacement (m)

θ is the angle between the force and the displacement

Work

PRACTICE

1. An emergency worker applies a force of 16 N to push a patient horizontally for 2.5 m on a gurney with nearly frictionless wheels. Determine the work done in pushing the gurney if the force is applied:
   (a) horizontally.

   (a) W = 40 J ☞ θ = 0°

Work

PRACTICE

1. An emergency worker applies a force of 16 N to push a patient horizontally for 2.5 m on a gurney with nearly frictionless wheels. Determine the work done in pushing the gurney if the force is applied:
   (b) at an angle of 25° below the horizontal.

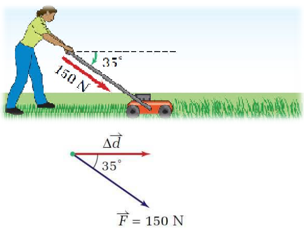
   (b) W = 36 J

Work

PRACTICE

2. A woman pushes a lawnmower with a force of 150 N at an angle of 35° down from the horizontal. The lawn is 10 m wide and requires 15 complete trips across and back. How much work does she do?

   W = 3.7 x 10^4 J

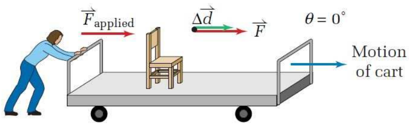


Positive Work

In the gurney problem, the work done was positive because the force and displacement were in the same direction. ***Positive work*** *indicates an increase in the energy of an object (i.e. the object speeds up, the height increases, ...)*

POSITIVE WORK

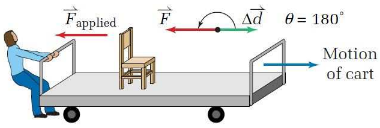
- the force and displacement are in the same direction
- object's energy increases – speeds up, height increases, ...



Negative Work

However, if the force is opposite to the direction of the displacement, negative work is done. ***Negative work*** *means a decrease in the energy of an object (i.e. the object slows downs, the height decreases, ...). For example, a force of kinetic friction does negative work on an object.*

NEGATIVE WORK
- the force and displacement are in opposite directions
- object's energy decreases – slows down, height decreases, ...



Negative Work

PRACTICE

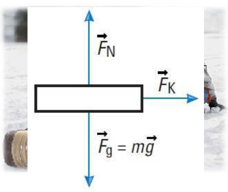
3. A toboggan carrying several children (total mass = 100 kg) reaches its maximum speed at the bottom of a hill, and then glides 10 m along a horizontal surface before coming to a stop. The coefficient of kinetic friction between the toboggan and the snowy surface is 0.10.

Negative Work

PRACTICE

3. (a) Draw a FBD of the toboggan when it is gliding to a stop.
   (b) Determine the kinetic friction acting on the toboggan.

   (b) $F_f = \mu F_N = \mu F_g = \mu mg = 98$ N

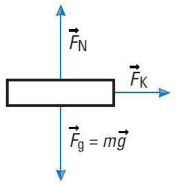


Negative Work

PRACTICE

3. (c) Calculate the work done by the kinetic friction.

(c) W = -980 J

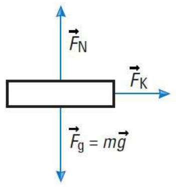


Negative Work

PRACTICE

3. (d) Why is the work done negative?

(d) because the force and displacement are in opposite directions



Zero Work

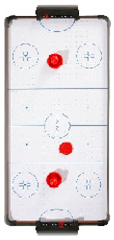
Situations exist in which an object experiences a force, or a displacement, or both, yet no work is done on the object. Consider the following:

1. *If you are holding a toolbox on your shoulder, you may be exerting an upward force on the toolbox, but the toolbox is not moving, so the displacement is zero, and the mechanical work done is also zero.*

Zero Work

Situations exist in which an object experiences a force, or a displacement, or both, yet no work is done on the object. Consider the following:

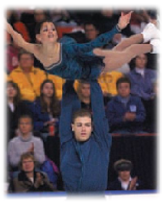
2. *If a puck on an air table is moving, it experiences negligible friction while moving for a certain displacement. The force in the direction of the displacement is zero, so the mechanical work done on the puck is also zero.*



Zero Work

Situations exist in which an object experiences a force, or a displacement, or both, yet no work is done on the object. Consider the following:

3. *Consider a skater who glides along the ice while holding his partner above his head. There are both a force on the partner and a horizontal displacement. However, the displacement is perpendicular to the force, so no mechanical work is done on the girl. (Of course, work was done in lifting the girl vertically to the height shown.)*



Zero Work

ZERO WORK

- situation in which no work is done on an object
  - ① $F = 0$
  - ② $d = 0$
  - ③ $F \perp d$ ☜ $\cos 90^\circ = 0$

Zero Work

PRACTICE

4. A student pushes against a large maple tree with a force of magnitude 250 N. How much work does the student do on the tree?

   zero since the displacement is zero

Zero Work

PRACTICE

5. A 500 kg meteoroid is travelling through space far from any measureable force of gravity. If it travels at 100 m/s for 1000 years, how much work is done on the meteoroid?

   zero since the force is zero

Zero Work

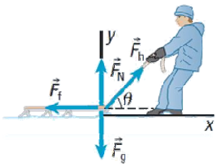
PRACTICE

6. A nurse holding a newborn 3.0 kg baby at a height of 1.2 m off the floor carries the baby 15 m at a constant velocity along a hospital corridor. How much work has the force of **gravity** done on the baby?

   zero since the force and displacement are perpendicular

Work & Multiple Forces

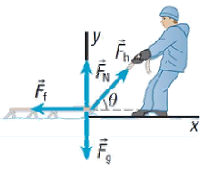
Almost all real-world examples of work involve friction plus other forces. In summary, when analyzing the total work done on an object, all forces that are present, including friction, must be considered. The net effect of these forces can result in either positive, negative, or zero total work being done on the object.



Work & Multiple Forces

PRACTICE

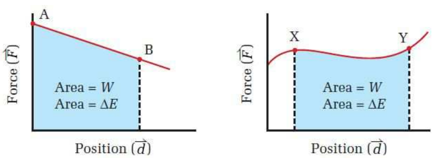
7. A hiker pulls a sled a distance 345 m with a constant force of 135 N exerted at an angle of 48°. Friction acts on the sled with a constant force of 67.0 N. Calculate the work done on the sled by (i) the hiker and (ii) friction, and (iii) the total work done on the sled.



(i) $W_{hiker} = 3.1 \times 10^4$ J
(ii) $W_{friciton} = -2.3 \times 10^4$ J
(iii) $W_{total} = 8.0 \times 10^3$ J

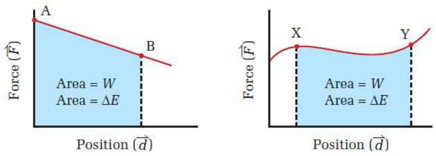
Work & Energy Change with a Variable Force

Until now, the force in the formula W=Fdcosθ was assumed to be constant. However, there are many examples in which the applied force varies with displacement. For example, the more an archery bow string is pulled back, the greater the force that the string can exert on the arrow. Force increases with the amount of stretch in a trampoline. Springs can exert forces when they are stretched or compressed.



Work & Energy Change with a Variable Force

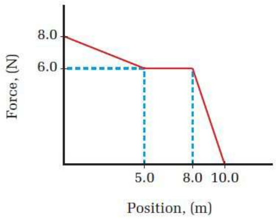
Since work is defined as the product of force times the displacement over which the force acts, then work must be equivalent to the graphical area under a graph of force versus position (displacement is a change in position). In the simplest cases, the graphical area forms a figure for which the area can be readily determined. In others, the area is more difficult to calculate.



Work & Energy Change with a Variable Force

PRACTICE

8. The graph shows the variation of applied force with displacement. Determine the work done by the force from:
   (a) 0-5 m 35 J
   (b) 5-8 m 18 J
   (c) 8-10 m 6.0 J
   (d) 0-10 m 59 J



✔ Check Your Learning

TEXTBOOK

P.170 Q.1-6 (Review)