PHYSICS
Work & Energy Study Guide

Work

Work is a force applied over a displacement. To calculate work, use the equation

$$W = F \cdot d$$

W = work (J) F = magnitude of applied force (N) d = magnitude of displacement (m)

After calculating the value of the work, you must give it the correct +/- sign according to these rules:

- If the force and displacement are in the same direction, work is positive (+)
- If the force and displacement are in opposite directions, work is negative (-)
- If the force and displacement are perpendicular, the work is zero

Work is measured in Joules (J):

$$1\ \text{Joule} = 1\ \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$$

Power

Power is a measure of how quickly work is performed. To calculate power, use the equation

$$P = \frac{W}{t}$$

P = power (W) W = work performed (J) t = time to perform the work (s)

Power is measured in Watts (W):

$$1\ \text{Watt} = 1\ \frac{\text{J}}{\text{s}}$$

Kinetic Energy

Kinetic energy (KE) is energy associated with motion. Whenever an object is moving, it has kinetic energy. To calculate KE, use the equation

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

KE = kinetic energy (J) m = mass (kg) v = velocity (m/s)

KE is always positive. Since velocity is squared in the equation for KE, changing velocity has a greater effect on KE than changing mass. For example, doubling mass doubles KE, but doubling velocity quadruples (4-times) the KE.

KE is measured in Joules (J).

Work-Kinetic Energy Theorem

The *Work-Kinetic Energy theorem* says that when work is performed on a system and the only change is the speed of the system, then the net work done equals the change in the KE of the system:

$$W_{net} = \Delta KE = KE_f - KE_i$$

W_{net} = net work (J)
ΔKE = change in KE (J)

In other words, work is a form of energy transfer.

Open/Closed Systems

A *system* is some portion of the Universe that you are focusing on.

An *open system* is a system that allows energy to be transferred in or out of the system.

A *closed system* is a system that does *not* allow energy to be transferred in or out of the system.

Conservation of Energy

The *conservation of energy* can be expressed in these equivalent ways:

- Energy is neither created nor destroyed, it can only be transformed into different forms
- There is a total amount of energy in the entire Universe that does not change
- In a closed system, the total amount of energy never changes
- In an open system, the amount of energy leaving the system equals the amount of energy entering the environment

Potential Energy

Potential energy is energy associated with position. There are two main types of potential energy, gravitational potential energy (GPE) and elastic potential energy (EPE). GPE is potential energy associated with the height of the system. To calculate it, use the equation

$$GPE = mgh$$

GPE = gravitational potential energy (J)
m = mass of the system (kg)
g = 9.81 m/s^2
h = height of the system (m)

EPE is potential energy associated with a system being stretched or compressed. For example, when a rubber band or a spring is stretched or compressed, EPE is stored. To calculate EPE, use the equation

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

EPE = elastic potential energy (J)
k = spring constant (N/m)
x = distance system is stretched or compressed (m)

The spring constant, *k*, is a measure of how difficult the object is to stretch.

Mechanical Energy

Mechanical energy is defined as the sum of the kinetic energy and potential energy (both gravitational and elastic PE) of the system.

$$ME = KE + GPE + EPE$$

ME = mechanical energy (J)
KE = kinetic energy (J)
GPE = gravitational potential energy (J)
EPE = elastic potential energy (J)

Conservation of Mechanical Energy

Mechanical energy of a system is *conserved*, meaning its value does not change, when the following two conditions are met:

- No energy enters or exits the system (no work is performed on the system)
- No friction or air resistance is present in the system

Conservation of ME explains the movement of systems like rollercoasters, pendula, and skateboarders on a ramp. The KE and GPE are inversely proportional to each other. When one increases, the other decreases. As the system moves up and down or swings, there is a continual transformation between KE and GPE. However, the KE and GPE change in such a way that their sum, the mechanical energy, never changes.

Friction and Mechanical Energy

When friction is present in a system, mechanical energy will not be conserved (its value will decrease). Friction causes mechanical energy to be converted into internal energy.

Practice Problems

A man pushes a box 10.0 meters across the floor in 10 seconds. He pushes with 25 N of force.

- Calculate the work performed. (250 J)
- Calculate the power. (25 Watts)

A man pulls a wagon with a force of 15 N in a straight-line distance of 100 m for 2 minutes.

- Calculate the work performed. (1500 J)
- Calculate the power. (12.5 Watts)

A man with a mass of 90 kg walks up stairs to the second level of this building. The height difference is 4.0 m. He does this in 8 seconds.

- Calculate the work performed. (3600 J)
- Calculate the power. (450 Watts)

A crane raises a crate 20 meters above the ground in 1 minute. The mass of the crate is 600 kg.

- Calculate the work performed. (120,000 J)
- Calculate the power. (2000 Watts)

A man with a mass of 75 kg walks up stairs to the second level of this building. The height difference is 5.0 m. Calculate the GPE. (3750 J)

A crane raises a crate 20 meters above the ground. The mass of the crate is 500 kg. Calculate the GPE. (100,000 J)

A car has a mass of 500 kg. It is moving with a velocity of 25 m/s. Calculate the KE of the car. (156,250 J)

An airplane has a mass of 16,000 kg. It is moving with a velocity of 190 m/s. Calculate the KE of the airplane. (288,800,000 J)

Julie pulls a wagon up an incline to the barn. The mass of the wagon is 120 kg. The rise height of the incline is 2.5 m. The slope length of the incline is 13.0 m. Calculate the force required to pull the wagon. (W = 3000 J; F = 231 N)

Practice Problems

1. Which of the following is an example of kinetic energy?
   A. A child jumping rope.
   B. A swimmer ready to dive.
   C. A toy lying on a table
   D. Firewood stacked in a fireplace.

2. In which situation is potential energy increasing?
   A. Pulling a wagon up a hill.
   B. Emptying a bucket of water.
   C. A cat jumping down from a tree.
   D. A car stopping at the traffic signal.

3. A pitcher throws a baseball. Which object has the most kinetic energy?
   A. The pitcher.
   B. The catcher
   C. The batter
   D. The baseball

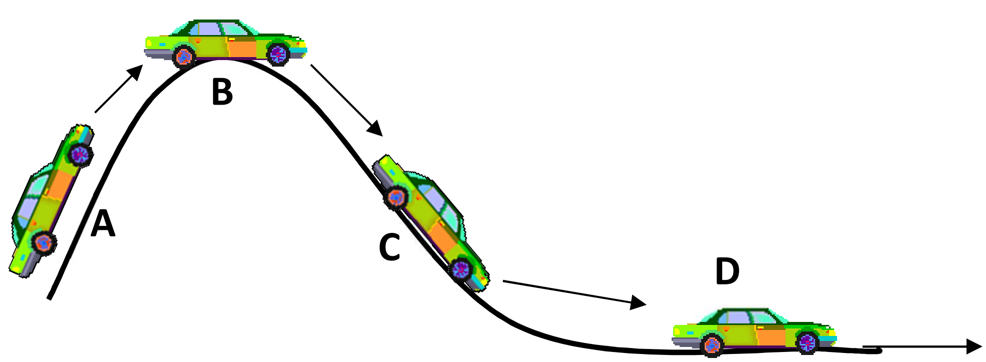
4. A man has a mass of 130 kg. He stands atop a cliff 100 meters above the valley floor. Calculate his gravitational potential energy.
   A. 1.3 J
   B. 1300 J
   C. 13,000 J
   D. 130,000 J

5. All objects that have kinetic energy must be
   A. Motionless
   B. Rolling
   C. Performing work
   D. Moving

6. A hammer has a mass of 0.50 kg. The hammer falls to the floor with a speed of 10 m/s. Calculate the kinetic energy of the hammer.
   A. 2.5 J
   B. 5.0 J
   C. 25 J
   D. 50 J

7. See the diagram below. At which position does the car have the greatest potential energy?
   A. Position A
   B. Position B
   C. Position C
   D. Position D

8. See the diagram below. At which position does the car probably have the greatest kinetic energy?
   A. Position A
   B. Position B
   C. Position C
   D. Position D



9. You hold a 5.0 kg object in your hand. You hold the object exactly 1 meter above the ground. How much work are you performing on the object at that instant in time?
   A. 0 J
   B. 5.0 J
   C. 50.0 J
   D. 500 J

10. Jerry pushes a wagon with a force of 70 N for a distance of 30 meters in 30 seconds. Teddy pushes a wagon with a force of 70 N for a distance of 30 meters in 40 seconds.
A. Jerry performed more work and used more power than Teddy.
B. Teddy performed more work and used more power than Jerry.
C. Jerry and Teddy performed equal work, but Jerry used more power.
D. Jerry and Teddy performed equal work, but Teddy used more power.
E. Jerry and Teddy performed equal work and used equal power.

11. Jerry pushes a wagon with a force of 80 N for a distance of 30 meters in 30 seconds. Teddy pushes a wagon with a force of 40 N for a distance of 60 meters in 30 seconds.
A. Jerry performed more work and used more power than Teddy.
B. Teddy performed more work and used more power than Jerry.
C. Jerry and Teddy performed equal work, but Jerry used more power.
D. Jerry and Teddy performed equal work, but Teddy used more power.
E. Jerry and Teddy performed equal work and used equal power.

12. Jerry pushes a wagon with a force of 80 N for a distance of 30 meters in 30 seconds. Teddy pushes a wagon with a force of 60 N for 30 meters in 30 seconds.
A. Jerry performed more work and used more power than Teddy.
B. Jerry performed more work and used less power than Teddy.
C. Jerry and Teddy performed equal work, but Jerry used more power.
D. Jerry and Teddy performed equal work, but Teddy used more power.
E. Jerry and Teddy performed equal work and used equal power.

13. The total energy attributed to an object (e.g., the system) may be transformed from one type of energy to another type of energy, but no energy is lost or gained.
A. Never true B. Sometimes true C. Always true D. It may happen if work occurs.

14. An object has a mass of 25 kg. The object lies motionless on a table 1.2 meters above the floor. Calculate its kinetic energy.
A. 0 J B. 18 J C. 30 J D. 300 J

15. An object has a mass of 25 kg. The object lies motionless on a table 1.2 meters above the floor. Calculate its gravitational potential energy.
A. 0 J A. 0 J A. 0 J A. 0 J

16. Friction is work that always occurs _________ .
A. In the same direction as the object's motion.
B. In the opposite direction of the object's motion.
C. Both in the same direction and in the opposite direction.
D. Depends on which type of object is in motion.

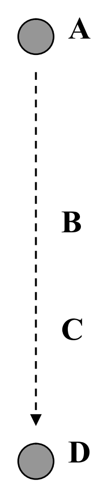
17. An object freefalls. What is causing work to be performed upon the object?
A. Gravity B. Mass of the object C. Air resistance D. Wind

18. If you stretch a spring, _______ produces _______ .
- A. Work against gravity; gravitational potential energy
- B. Work against resistance; elastic potential energy
- C. Mechanical work; kinetic energy
- D. Work against shape; chemical energy

19. If you lift an object, ______ produces _______.
- A. Work against gravity; gravitational potential energy
- B. Work against resistance; elastic potential energy
- C. Mechanical work; kinetic energy
- D. Work against shape; chemical energy

20. According to the work-energy theorem…
- A. All types of work will produce energy; all types of energy can produce work.
- B. All types of work will produce energy; energy cannot produce work.
- C. All types of energy will produce work; work cannot produce energy
- D. Energy cannot produce work; work cannot produce energy.

21. According to the Law of Conservation of Energy…
- A. Energy can be converted into work.
- B. Work can be converted into energy.
- C. Energy is neither gained nor destroyed.
- D. The total energy is slowly decreases.



22. What best describes the energy relationship at position A?
- A. Total energy = 100% GPE + 0% KE
- B. Total energy = 75% GPE + 25% KE
- C. Total energy = 50% GPE + 50% KE
- D. Total energy = 25% GPE + 75% KE
- E. Total energy = 0% GPE + 100% KE

23. What best describes the energy relationship at position C?
- A. Total energy = 100% GPE + 0% KE
- B. Total energy = 75% GPE + 25% KE
- C. Total energy = 50% GPE + 50% KE
- D. Total energy = 25% GPE + 75% KE
- E. Total energy = 0% GPE + 100% KE

24. What best describes the energy relationship at position B?
- A. Total energy = 100% GPE + 0% KE
- B. Total energy = 75% GPE + 25% KE
- C. Total energy = 50% GPE + 50% KE
- D. Total energy = 25% GPE + 75% KE
- E. Total energy = 0% GPE + 100% KE

1. James pushed a crate with a force of 30 N for a distance of 30 m in 20 seconds. (assume no friction). • Calculate work. • Calculate power.	2. A crane lifted a block of cement to a height of 80 meters in 75 seconds. The mass of the block was 300 kg. • Calculate work. • Calculate power.

25. A rocket behaves like a vertical projectile. A rocket blasts off from the launch pad. The mass of the rocket is 50 kg. Assume no mass change. The launch velocity is 80 m/s.

TOTAL ENERGY = ____________________

GPE at 0 m (launch) = ____________________

KE at 0 m (launch) ____________________

GPE at maximum height = ____________________

KE at maximum height = ____________________

Maximum height = ____________________

GPE at 200 m above ground = ____________________

KE at 200 m above ground = ____________________

Velocity at 200 m above ground = ____________________

26. You drop a rock from a height of 200 m. It impacts the ground. The mass of the rock is 40 kg. Assume no mass change.

TOTAL ENERGY = ____________________

GPE at 200 m (release) = ____________________

KE at 200 m (release) ____________________

GPE at 120 m = ____________________

KE at 120 m = ____________________

Velocity at 120 m = ____________________

GPE at impact = ____________________

KE at impact = ____________________

Velocity at impact = ____________________