

- **Equations and important notes:**

1. Kinetic Energy:

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

$$\Delta K.E = \frac{1}{2}m(v_f^2 - v_i^2)$$

- K.E is a **scalar** quantity (has **no** direction) and measured in **Joules = N.m = Kg. $\frac{m^2}{s^2}$**
- The **change** in K.E could be **+** (Object is speeding up) or **-** (Object is slowing down).

2. Work Done by a constant force:

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

- θ : Is the angle **between** Force vector [F] and displacement vector [d]
- If [F] **opposite** in direction to [d], then Work is **Negative**.
- If [F] in the **same** direction as [d], then Work is **Positive**.
- Work is a **scalar** quantity and also, measured in Joules as energy.
- Force of **gravity** is an example of **constant** force. the work done by it can be written as:

$$W_g = mgh \begin{cases} + \text{ (When lowering the object) } \\ - \text{ (When lifting the object) } \end{cases}$$

3. Work Done by a variable force:

$$W = \int_{x_i}^{x_f} F(x) \cdot dx$$

Steps to find the work done by a variable force:

- 1) You will have a force function [F(x)], Integrate this function by:
 - a. Add 1 to exponent.
 - b. Divide by the new exponent (the exponent after adding 1 to it.)
 - c. add x to constant. (e.g.: 5 will be 5x).
- 2) substitute the values of x in the function you got after integration, by substituting the **final value minus** the **initial value**.

An example of variable force is Spring force, where the work done by spring is:

$$F_s = -k\Delta x$$

$$W_s = \frac{1}{2}k x_i^2 - \frac{1}{2}k x_f^2$$

- The **negative sign** in the Spring force equation is because that spring force is opposite in direction to displacement.
- Work done by spring is **negative**.

- **K**: is the **spring constant** that represent the hardness of spring (How hard to compress or extend a spring) in **N/m**. and it represent the **slope** of (force – displacement graph).
- If you are given a graph instead of force function, we find the **Area under the curve** of force-displacement graph.

4. Work-Kinetic Energy theorem:

$$W = \Delta K.E$$

$$F \cdot d \cos\theta = \frac{1}{2} m (v_f^2 - v_i^2)$$

5. Power:

$$Power = \frac{Work}{\Delta t} = \frac{\Delta K.E}{\Delta t} = F \cdot v \cos\theta$$

- Power is a scalar quantity and measured in **Watt = J/s = Kg. $\frac{m^2}{s^3}$**
- **1 hp = 746 watt**
(To Convert from **hp to watt** $\times 746$, to convert from **watt to hp** $\div 746$).

Extra notes:

- Force of friction is calculated by:

$$F_k = \mu_k F_n$$

For Horizontal surfaces:

$$F_k = \mu_k mg$$

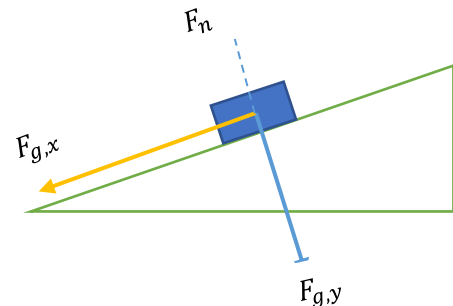
For Inclined surface:

$$F_k = \mu_k mg \cos\theta$$

θ : the angle of inclination.

- $F_{g,x} = mg \sin\theta$
➤ $F_{g,y} = mg \cos\theta$

- Constant velocity, means **a = 0**, $\Sigma F_{net} = 0$



Exam Questions

Q.1	Which of the following is a correct unit of energy? a) kg m/s^2 c) $\text{kg m}^2/\text{s}^2$ e) $\text{kg}^2 \text{ m}^2/\text{s}^2$ b) $\text{kg m}^2/\text{s}$ d) $\text{kg}^2 \text{ m/s}^2$
Q.2	Shamsa climbs a flight of stairs. What can we say about the work done by gravity on her? a) Gravity does negative work on her. c) Gravity does no work on her. b) Gravity does positive work on her. d) We can't tell what work gravity does on her.
Q.3	If negative work is being done by an object, which one of the following statements is true? a) An object is moving in the negative x-direction. b) An object has negative kinetic energy. c) Energy is being transferred from an object. d) Energy is being transferred to an object.
Q.4	5.10 A skydiver is subject to two forces: gravity and air resistance. Falling vertically, he reaches a constant terminal speed at some time after jumping from a plane. Since he is moving at a constant velocity from that time until his chute opens, we conclude from the work-kinetic energy theorem that, over that time interval, a) the work done by gravity is zero. b) the work done by air resistance is zero. c) the work done by gravity equals the negative of the work done by air resistance. d) the work done by gravity equals the work done by air resistance. e) his kinetic energy increases.

Q.5	5.15 If the net work done on a particle is zero, what can be said about the particle's speed?
Q.6	5.18 A car, of mass m, traveling at a speed v_1 can brake to a stop within a distance d. If the car speeds up by a factor of 2, so that $v_2 = 2v_1$, by what factor is its stopping distance increased, assuming that the braking force F is approximately independent of the car's speed?
Q.7	5.20 A limo is moving at a speed of 100 km/h. If the mass of the limo, including passengers, is 1900 kg, what is its kinetic energy?
Q.8	5.25 What is the kinetic energy of an ideal projectile of mass 20.1 kg at the apex (highest point) of its trajectory, if it was launched with an initial speed of 27.3 m/s and at an initial angle of 46.9° with respect to the horizontal?

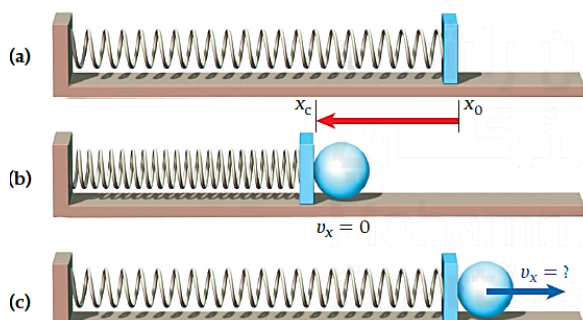
Q.9

5.29 A hammerhead of mass $m = 2.00$ kg is allowed to fall onto a nail from a height $h = 0.400$ m. Calculate the maximum amount of work it could do on the nail.

Q.10

5.32 A father pulls his son, whose mass is 25.0 kg and who is sitting on a swing with ropes of length 3.00 m, backward until the ropes make an angle of 33.6° with respect to the vertical. He then releases his son from rest. What is the speed of the son at the bottom of the swinging motion?

Q.11



SOLVED PROBLEM 5.2

Compressing a Spring

A massless spring located on a smooth horizontal surface is compressed by a force of 63.5 N, which results in a displacement of 4.35 cm from the initial equilibrium position. As shown in Figure 5.16, a steel ball of mass 0.075 kg is then placed in front of the spring and the spring is released.

PROBLEM

What is the speed of the steel ball when it is shot off by the spring, that is, right after it loses contact with the spring? (Assume there is no friction between the surface and the steel ball; the steel ball will then simply slide across the surface and will not roll.)

Answers:

1. C
2. A
3. D
4. C
5. Constant (Doesn't change)
6. breaking distance will Increases by a factor of **4**.
7. $K.E = 7.33 \times 10^5 \text{ J}$
8. $K.E = 3.5 \times 10^3 \text{ J}$
9. $W = 7.85 \text{ J}$
10. $V = 3.14 \text{ m/s}$
11. $V = 6.1 \text{ m/s}$

Extra Questions to practice

5.5 A constant force, $\vec{F} = (4.79, -3.79, 2.09)$ N, acts on an object of mass 18.0 kg, causing a displacement of that object by $\vec{r} = (4.25, 3.69, -2.45)$ m. What is the total work done by this force?

5.6 How much work is done when a 75.0-kg person climbs a flight of stairs 10.0 m high at constant speed?

- a) 7.36×10^5 J c) 75 J e) 7360 J
b) 750 J d) 7500 J

5.7 Does the Earth do any work on the Moon as the Moon moves in its orbit?

5.8 Suppose you pull a sled with a rope that makes an angle of 30.0° to the horizontal. How much work do you do if you pull with 25.0 N of force and the sled moves 25.0 m?

Think about the answers to these questions next time you are driving a car:

- a) What is the kinetic energy of a 1500 kg car moving at 15.0 m/s?
- b) If the car changed its speed to 30.0 m/s, how would the value of its kinetic energy change?

5.11 Jack is holding a box that has a mass of m kg. He walks a distance of d m at a constant speed of v m/s. How much work, in joules, has Jack done on the box?

- a) mgd
- b) $-mgd$
- c) $\frac{1}{2}mv^2$
- d) $-\frac{1}{2}mv^2$
- e) zero

5.27 Two baseballs are thrown off the top of a building that is 7.25 m high. Both are thrown with initial speed of 28.4 m/s. Ball 1 is thrown horizontally, and ball 2 is thrown straight down. What is the difference in the speeds of the two balls when they touch the ground? (Neglect air resistance.)

•**5.38** A particle of mass m is subjected to a force acting in the x -direction. $F_x = (3.00 + 0.500x)$ N. Find the work done by the force as the particle moves from $x = 0.00$ to $x = 4.00$ m.

•**5.39** A force has the dependence $F_x(x) = -kx^4$ on the displacement x , where the constant $k = 20.3$ N/m⁴. How much work does it take to change the displacement, working against the force, from 0.730 m to 1.35 m?

5.42 An ideal spring has the spring constant $k = 440$ N/m. Calculate the distance this spring must be stretched from its equilibrium position for 25.0 J of work to be done.

5.43 A spring is stretched 5.00 cm from its equilibrium position. If this stretching requires 30.0 J of work, what is the spring constant?

• **5.45** A spring with a spring constant of 238.5 N/m is compressed by 0.231 m. Then a steel ball bearing of mass 0.0413 kg is put against the end of the spring, and the spring is released. What is the speed of the ball bearing right after it loses contact with the spring? (The ball bearing will come off the spring exactly as the spring returns to its equilibrium position. Assume that the mass of the spring can be neglected.)

5.49 A car of mass 1214.5 kg is moving at a speed of 27.9 m/s when it misses a curve in the road and hits a bridge piling. If the car comes to rest in 0.236 s, how much average power (in watts) is expended in this interval?

5.50 An engine expends 40.0 hp in moving a car along a level track at a speed of 15.0 m/s. How large is the total force acting on the car in the direction opposite to the motion of the car?

• **5.51** A car of mass 942.4 kg accelerates from rest with a constant power output of 140.5 hp. Neglecting air resistance, what is the speed of the car after 4.55 s?

5.62 The mass of a physics textbook is 3.40 kg. You pick the book up off a table and lift it 0.470 m at a constant speed of 0.270 m/s.

- What is the work done by gravity on the book?
- What is the power you supplied to accomplish this task?

Answers

1. $W = 1.25 \text{ J}$
2. e
3. No, because the angle between the attraction force between earth and displacement is 90° , so $\cos 90 = 0$ and thus, work $= 0$.
4. $W = 541.3 \text{ J}$
5. $K.E = 1.69 \times 10^5 \text{ J}$
 $\Delta K.E = 5.06 \times 10^5 \text{ J}$
6. e
7. **No change** and no need to do any calculation because the K.E doesn't depend on the directions, so once both released with the same speed and from the same height that mean no difference.
8. $W = 16 \text{ J}$
9. $W = 17.4 \text{ J}$
10. $x = 0.34 \text{ m}$
11. $k = 2.4 \times 10^4 \text{ N/m}$
12. $V = 17.55 \text{ m/s}$
13. $P = 2.01 \text{ MW}$
14. $F = 1990 \text{ KN}$
15. $V = 31.8 \text{ m/s}$
16. $W_g = -15.7 \text{ J}$
 $P = 9 \text{ W}$