Work and Energy Notes

Work – The product of the components of a force along the direction of displacement and the magnitude of the displacement. Work is a *scalar* value.

$$W = F \cdot d$$

The SI unit for Work and Energy is the **Joule [J]**, which represent a **Newton·meter [N·m]**

The above formula only works if F and d are in the *same direction*.

Work is only done when *components of a force are parallel to the displacement.*

Therefore, if we define the angle θ to be the angle between the displacement vector and the force vector, the equation transforms into

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

If more than one force is acting on an object, you can find the *net work* done on the object by first find the *net force* on the object.

$$W_{net} = F_{net} \cdot d \cdot \cos(\theta)$$

Example: How much work is done on a box that is pushed 10 meters across a horizontal floor by a force of 50N at an angle 20° above the horizontal.

Try more for yourself. Page 162 Practice A. Answers: (1) 1.5×10^7 J (2) 7.0×10^2 J (3) 1.6×10^3 J (4) 1.1 m

Kinetic Energy: The energy of an object that is due to the object's motion. It dependent on both the mass and the velocity of an object.

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

Example: A 500kg go-kart is moving at a constant speed of 6 m/s. If my mass is 65 kg, how fast would I have to be moving to have the same kinetic energy of the go-cart?

Try more for yourself. Page 166 Practice B. Answers: (1) 1.7×10^2 m/s (2) 38.8 m/s (3) the bullet with greater mass, 2 to 1. (4) 2.4 J, 9.6 J, the bullet with greater speed, 1 to 4. (5) 1.6×10^3 kg

Work-Kinetic Energy Theorem: The net work done by all the forces acting on an object is equal to the change in the object's kinetic energy.

$$W_{net} = \Delta KE$$

Example: How much work does it take to get an 800 kg car to 15 m/s if it started from rest?

Example: On a frozen pond, a person kicks a 10 kg sled, giving it an initial speed of 2.2 m/s. How far does the sled move if the coefficient of kinetic friction between the sled and the ice is 0.10? (page 167)

Try more for yourself. Page 168 Practice C. Answers: (1) 7.8 m (2) 21 m (3) 5.1 m (4) 3.0 x 10^2 N

Potential Energy: The energy associated with an object because of the position, shape, or condition of the object.

Gravitational Potential Energy: The potential energy stored in the gravitational fields of interacting bodies.

$$PE_g = m \cdot g \cdot h$$

(where m is mass, g is gravitational acceleration constant, and h is height)

Example: What is the change in potential energy for a diver from when he jumps off a 10 m high cliff and when he first hits the water?

Elastic Potential Energy: The energy available for use when a deformed elastic object returns to its original configuration.

$$PE_{elastic} = \frac{1}{2}kx^2$$

(where k is the spring constant and x is the distance compressed or stretched)

Spring Constant: a parameter that is a measure of a spring's resistance to being compressed or stretched.

Example: A spring with a spring constant of 15 N/m has an relaxed length of 1.0 m. If the spring is stretched to 2.5 m, what is the elastic potential energy stored in the spring?

Try more for yourself. Page 172 Practice D. Answers: (1) 3.3 J (2) 3.1 x 10^{-2} J (3) a. 785 J b. 105 J c. 0.00 J

Mechanical Energy: the sum of kinetic energy and all forms of potential energy.

$$ME = KE + PE_{total}$$

(All energy, such as nuclear, chemical, internal, electrical, that is not mechanical energy will be called nonmechanical energy, we will not use this for now)

Conservation of Mechanical Energy: In the absence of friction and other *nonconservative* forces, the total amount of mechanical energy in a system will remain constant.

$$ME_i = ME_f$$

Example: I want to know the speed a bowling ball will reach if rolled down a 3m high ramp starting from rest. Let's say the bowling ball has a 4 kg mass and we can assume the interaction between the ball and the ramp is frictionless.

Example: A spring of force constant 20 N/m is attached to a stable wall on one end. The other end is attached to a 3 kg mass which is pushed toward the wall and compresses the spring 35 cm. If the person let's go of the mass, what is velocity of the mass when it passes through its starting position?

Try more for yourself. Page 177 practice E. Answers: (1) 20.7 m/s (2) 9.9 m/s; 14.0 m/s (3) 14.1 m/s (4) 0.25 m (5) 0.18 m

Power: A quantity that measures the rate at which work is done or energy is transformed.

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

(The SI unit for power is the Watt [W] which is defined as joules per second [J/s])

Example: A weightlifter wants to bench 100 kg in 0.8 seconds. For his body size, a correct lift involves moving the weight directly upward at a *constant speed* for 0.7 m. What is the power supplied by the weightlifter in this process.

$$P = \frac{W}{\Delta t} = F\frac{d}{\Delta t} = Fv$$

(Alternative formula for constant speed situations)

Example: A 30 kg crate needs to be pushed across the floor at a constant speed of 2 m/s. If the kinetic frictional force in this situation is 90 N, then what power must be applied to the crate?

Try more for yourself. Page 181 Practice F. Answers: (1) 66 kW (2) 23.8 kW (3) 8.27 years (4) 1.0 hour (5) a. 7.5×10^4 J b. 2.50×10^4 W