Work-Energy Theorem

1. A 7.0 kg block is initially at rest on a frictionless horizontal surface. A constant horizontal force of 20 N is applied to it. Calculate the block's speed after it has moved 8.0 meters.
2. A 4.0 kg object is projected up a frictionless incline plane that makes a 45° angle with the horizontal. The object is given an initial speed of 147 m/s up the incline. How far along the incline does the object travel before coming to rest?
3. A spring with a force constant $k = 800\ N/m$ is compressed by 0.4 meters. A 4.5 kg block is placed against the spring on a horizontal surface with a coefficient of kinetic friction $\mu_k = 0.7$. When the spring is released, how far does the block travel before coming to a stop?
4. A 4 kg cart is moving at 10.0 m/s on a horizontal track when it collides with a light spring bumper of spring constant $k = 1000\ N/m$. What is the maximum compression of the spring?
5. A 5.0 kg object is moving at 16.0 m/s when it encounters a rough horizontal surface that brings it to rest over a distance of 9.0 meters. Calculate the coefficient of kinetic friction between the object and the surface.
6. A roller coaster car of mass 2000 kg starts from rest at the top of an 80 m high hill. Assuming no friction, what is its speed at the bottom of the hill?
7. A 100.0 kg box is pulled up a 15.0 m long incline plane inclined at 30° to the horizontal by a constant force of 90 N parallel to the incline. The coefficient of kinetic friction between the box and the incline is 0.5. Calculate the final speed of the box if it starts from rest.
8. A 0.2 kg pendulum bob is released from a height of 0.5 meters above its lowest point. Assuming no air resistance, calculate the speed of the bob at the lowest point.
9. A horizontal spring with a spring constant $k = 600\ N/m$ is attached to a wall. A 6.0 kg block compresses the spring by 0.7 m and is then released from rest. The surface is frictionless except for a rough patch 0.2 m long with a coefficient of kinetic friction $\mu_k = 0.4$. Determine the speed of the block after it passes the rough patch.
10. A bullet of mass 20 grams is fired horizontally into a 2.0 kg wooden block resting on a horizontal surface with a coefficient of kinetic friction of 0.5. The bullet embeds itself in the block, and the block slides 1.2 meters before coming to rest. Calculate the initial speed of the bullet.

Forces and Potential Energy

1. An object moves along the x-axis under the influence of a force given by $F(x) = x^3$. Calculate the work done by the force as the object moves from $x = 0$ to $x = 6$.
2. A particle of mass 2.0 kg is placed in a potential energy field given by $U(x) = 4x^3$, where x is in meters. Determine the force acting on the particle when it is at $x = 3$.

3. A conservative force F acts on a particle such that $F =- kx$, where k is positive constant. The potential energy associated with this force is zero at $x = 0$. Express the potential energy $U(x)$ as a function of x.
4. An object of mass 5.0 kg is released from rest at the top of a frictionless incline of height 10.0 m. At the bottom of the incline, it encounters a horizontal spring with a force constant $k = 300\ N/m$. How far does the spring compress before the object comes to rest?
5. A particle moves along the x-axis under the influence of a force given by $F(x) = x^2 + 5x$. Determine the potential energy function $U(x)$, assuming $U(0) = 0$.
6. A block of mass 1.5 kg is attached to a horizontal spring with a force constant of 250 N/m. The spring is compressed by 0.20 m and released from rest. Calculate the speed of the block as it passes through the equilibrium position.
7. An object is subjected to a conservative force described by the potential energy function $U(x) = 6x - 9$, where U is in joules and x is in meters. Find the force acting on the object.
8. A satellite is moving in a circular orbit around Earth at a height where the gravitational potential energy is $U =- 1.0 \times 10^9 J$. If the satellite's kinetic energy is $K = 5.0 \times 10^8 J$, calculate the total mechanical energy of the satellite and determine whether the satellite is in a bound or unbound orbit.

Conservation of Energy

1. A block of mass 0.5 kg is attached to a horizontal massless spring with a spring constant of 200 N/m. The block is initially at rest at the spring's equilibrium position. A constant horizontal force of 10 N is then applied to the block, stretching the spring.
    a. Calculate the maximum extension of the spring.
    b. Determine the work done by the applied force up to the point of maximum extension.
    c. If the applied force is suddenly removed at maximum extension, what is the speed of the block as it passes through the equilibrium position?
2. A 2.0 kg block is released from rest at the top of a frictionless incline that is 5.0 meters high and 10.0 meters long. The incline makes an angle θ with the horizontal.
    a. Calculate The angle θ of the incline.
    b. Calculate the acceleration of the block down the incline.
    c. Calculate the velocity of the block when it reaches the bottom of the incline.
    d. Calculate the time it takes for the block to reach the bottom.
3. A pendulum consists of a 12 kg mass attached to an 8 m long, massless string. The mass is pulled sideways until the string makes a 30° angle with the vertical and then released from rest, Neglecting air resistance.

   a. Calculate the vertical height at which the mass is raised above its lowest point.
   b. Determine the potential energy of the mass at the release point relative to the lowest point.
   c. Find the speed of the mass at the lowest point of its swing.
   d. Calculate the tension in the string at the lowest point.
4. A 500 kg roller coaster car starts from rest at the top of a 20-meter-high hill. It descends to ground level and then climbs up a 15-meter-high second hill, assuming no friction or air resistance.
   a. Determine the speed of the car at the bottom of the first hill.
   b. Calculate the speed of the car at the top of the second hill.
   c. If the car needs to just make it over the second hill without falling off the track, what is the minimum speed required at the top of the second hill?
   d. Does the car have enough speed to negotiate the second hill safely?
5. A small block of mass m = 0.5 kg is released from rest at a height h above the bottom of a loop-the-loop track with a radius $R = 2.0$ meters. The block slides down the track and around the loop. The track has a constant coefficient of kinetic friction $\mu_k = 0.10$ between the block and the track throughout the entire motion. Assume $g = 9.8\ m/s^2$.
   a. Determine the minimum height h above the bottom of the loop from which the block must be released so that it just barely makes it around the loop without losing contact at the top.
   b. Calculate the total mechanical energy lost due to friction by the time the block reaches the top of the loop.
   c. Find the normal force exerted on the block by the track when the block is at the bottom of the loop.
   d. If the block starts from the height calculated in part (a), determine its speed when it reaches the horizontal level of the center of the loop.

Power

1. A force acting on a particle moving along the x-axis varies with position according to $F(x) = x^2 + 3x - 4$ (in newtons), where x is in meters. The particle moves from $x = 0\ to\ x = 6$ meters.
   a. Calculate the work done by the force over this displacement.
   b. If the particle has a mass of 2 kg and starts from rest at $x = 2$, what is the velocity at $x = 6$?
2. A 10 kg crate initially at rest is pushed across a horizontal floor with a constant applied force of 60 N acting at an angle of 30° below the horizontal. The coefficient of kinetic friction between the crate and the floor is 0.20. The crate moves a distance of 5 meters.
   a. Calculate the normal force acting on the crate.

b. Determine the work done by the applied force.
c. Find the work done by the frictional force.
d. Calculate the net work done on the crate.
e. If the crate starts from rest, what is its final speed after moving 5 meters?

3. A motor lifts an elevator with a total mass of 1,200 kg (including passengers) vertically upward at a constant speed of 3 m/s.
   a. Calculate the tension force in the elevator cable.
   b. Determine the motor's power output required to lift the elevator at this speed.
   c. If the motor operates at this power for 20 seconds, how much work does it do?
4. A 1,500 kg car accelerates uniformly from rest to a speed of 20 m/s over a distance of 100 meters on a level road.
   a. Determine the average net force acting on the car.
   b. Calculate the net work done on the car during this acceleration.
   c. Assuming the engine operates at constant efficiency, calculate the average power output of the car's engine during this acceleration.
5. A 75 kg athlete runs up a staircase that is 10 meters high in 12 seconds.
   a. Calculate the work done against gravity.
   b. Determine the average power output in watts.
   c. If the athlete's body is only 25% efficient at converting chemical energy into mechanical work, how much total energy does the athlete expend during the climb?
6. A box of mass 4 kg is pushed along a horizontal surface by a force F that increases linearly with distance, given by $F(x) = 7x$ (in newtons), where x is the distance in meters. The coefficient of kinetic friction between the box and the surface is 0.10. The box starts from rest at $x = 0$ m.
   a. Calculate the net work done on the box as it moves from $x = 0$ to $x = 4$.
   b. Determine the velocity of the box at $x = 6$.
   c. Find the instantaneous power being delivered by the applied force at $x = 6$.
   d. Compute the total energy dissipated by friction over the 3-meter distance.