Homework Set: Lectures 5 & 6
Work, Energy, Power, Efficiency

Problem 1: Work and Mechanical Energy on an Incline

A $4.0kg$ box is pushed up a $30°$ incline by a constant horizontal force of $40N$. The box moves a distance of $3.0m$ along the incline. The coefficient of kinetic friction is $\mu_k = 0.20$. The box begins from rest.

(a) Draw a complete free-body diagram.

(b) Determine the work done by:

  (i) the applied horizontal force,

  (ii) gravity,

  (iii) the normal force,

  (iv) friction.

(c) Find the net work done on the box.

(d) Determine the final speed of the box using the work–energy theorem.

Problem 2: Spring and Gravitational Potential Energy Transformation

A $1.8kg$ block compresses a spring ($k = 500N/m$) by $0.15m$ on a horizontal surface. The spring launches the block which then travels across a rough horizontal surface ($\mu_k = 0.10$) for $2.0m$ before rising up a frictionless ramp.

(a) Find the initial elastic potential energy stored in the spring.

(b) Find the speed of the block just after it loses contact with the spring (assume the spring returns to its natural length without losses).

(c) Determine the work done by friction on the horizontal surface.

(d) Find the speed of the block at the base of the ramp.

(e) Determine the maximum vertical height it reaches on the ramp.

Problem 3: Power and Energy Transfer on a Moving Object

A crate of mass $25kg$ is pulled across the floor at a constant speed of $1.2m/s$ by a rope making a $35°$ angle above the horizontal. The coefficient of kinetic friction is $\mu_k = 0.30$.

(a) Draw a free-body diagram for the crate.

(b) Determine the tension in the rope.

(c) Calculate the power delivered by the person pulling the crate.

(d) If the person can sustain a maximum power output of $200W$, determine whether they can maintain this motion indefinitely.

Problem 4: Efficiency and Sankey Energy Accounting

A lifting machine raises a $180kg$ load vertically at a steady speed of $0.60m/s$. The motor draws electrical power at a rate of $3200W$. Internal friction forces total $350N$ opposing the motion.

(a) Determine the useful output power delivered by the machine.

(b) Compute the efficiency of the machine.

(c) Determine the rate at which energy is being converted into thermal energy (wasted power).

(d) Construct a Sankey-style diagram identifying the energy input rate and how it splits among useful output and losses.

Problem 5: Multi-Stage Energy System with Fuel Energy Density

A small generator uses gasoline with a specific energy of $45MJ/kg$. The generator runs a winch system that lifts a $250kg$ crate vertically upward a total height of $12m$. The winch motor is 72% efficient at converting electrical energy to mechanical energy. The generator is 28% efficient at converting chemical energy of fuel into electrical energy.

(a) Determine the mechanical work required to lift the crate.

(b) Find the amount of electrical energy the motor must receive from the generator.

(c) Determine the chemical energy input required from the fuel.

(d) Find the mass of gasoline consumed in performing this lift.

(e) Explain how the energy transfers could be represented in a Sankey diagram.