General Physical Science

Chapter 4
Work and Energy

Work

The work done by a constant force $F$ acting upon an object is the product of the magnitude of the force (or component of the force) and the parallel distance $d$ through which the object moves while the force is applied.

$W = F \cdot d$
**Work**

- Scalar quantity
  - Magnitude but no direction
- SI base unit = joule (J)
  - Units are N·m or kg m² / s²
- English - ft-pound
- Work is *against* another force.

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**Lifting**

- apply a force against gravity
- \( W = F \cdot d \) (Fd)
  - \( F = mg \)
  - Distance measured as height (against gravity) \( (h) \)
  - \( W = mgh \)
- Work against friction
  - constant velocity means net force = 0

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**Learning Goals**

- Define work.
- List the units for work

Questions: 1-5

Exercises: 1-7 odd
Kinetic and Potential Energy

- Work done on an object changes stuff.
  - Changes speed
  - Changes height
  - Produces heat
- All are changes in energy.
- Energy is the ability to do work
  - Work by a system decreases energy.
  - Work on a system increases energy.
- Work is the process by which energy is transferred from one object to another.

Energy

- Work and energy have the same units!
- Many forms of energy
  - Electrical
  - Chemical
  - Light
  - many others
- Focus here is on mechanical energy.

Mechanical Energy

- Two basic forms of mechanical energy
  - Kinetic energy
  - Energy of motion
  - \( E_k = \frac{1}{2} mv^2 \)
  - work done on a moving object, must calculate energy before and after, not just \( \Delta v \)
A 1.0 kg ball is fired from a cannon. What is the change in the ball’s kinetic energy when it accelerates from 4.0 m/s to 8.0 m/s?

Kinetic energy at 4.0 m/s
- \( E_k = \frac{1}{2} m v^2 \)
- \( = \frac{1}{2} \times 1.0 \times 4.0^2 \)
- \( = 8.0 \text{ J} \)

Kinetic energy at 8.0 m/s
- \( = \frac{1}{2} \times 1.0 \times 8.0^2 \)
- \( = 32 \text{ J} \)

Difference
- \( 32 \text{ J} - 8.0 \text{ J} = 24 \text{ J} \)
Mechanical Energy

- Potential energy
  - energy of position
  - Assuming position in gravitational field, then potential energy is the mass times g times the height of the object.
  - \( E_p = mgh \)

- Work against gravity:
  - \( \Delta E_g = mg\Delta h \)

Potential Energy

- Height is independent of the path used to obtain the height!
- ‘Height’ (actually \( \Delta h \)) can be positive or negative.
- Other types of potential energy
  - Spring
  - Bow
  - etc.

Kinetic and Potential Energy

- Learning Goals
  - Explain the relationship between work and energy.
  - Define and distinguish kinetic and potential energies.

- Questions: 6-11
- Exercises: 9-15 odd
Conservation of Energy

- The total energy of an isolated system remains constant.
- Conservation of mechanical energy
  - \( (E_x + E_p)_{t_1} = (E_x + E_p)_{t_2} \)
  - \( \frac{1}{2} m v^2 + mgh \) \(_{t_1} = \frac{1}{2} m v^2 + mgh \) \(_{t_2} \)

Example

- A 0.10 kg stone is dropped from a height of 10 m. What will the kinetic and potential energies of the stone be at 10.0 m, 7.0 m, 3.0 m, and 0.0 m. Be sure to neglect air resistance.
- At 10 m
  - \( E_p = mgh = (0.10)(9.8)(10.0) = 9.8 \text{ J} \)
  - \( E_k = 0 \text{ J}; \text{ therefore total energy} = 9.8 \text{ J} + 0 \text{ J} = 9.8 \text{ J} \)

Example

- Total energy = 9.8 J
- At 7.0 m
  - \( E_p = mgh = (0.10)(9.8)(7.0) = 6.9 \text{ J} \)
  - \( E = E_k + E_p \)
  - \( 9.8 \text{ J} = 6.9 \text{ J} + x \)
  - \( x = 9.8 \text{ J} - 6.9 \text{ J} = 2.9 \text{ J} \)
Example

- Total energy = 9.8J
- At 3.0 m
  - \( E_p = mgh = (0.10)(9.8)(3.0) = 2.9J \)
  - \( E = E_p + E_k \)
  - 9.8J = 2.9J + x
  - x = 9.8J - 2.9J = 6.9J

Example

- Total energy = 9.8J
- At 0.0 m
  - \( E_p = mgh = (0.10)(9.8)(0.0) = 0.0J \)
  - \( E = E_p + E_k \)
  - 9.8J = 0.0 + x
  - x = 9.8J - 0.0J = 9.8J

Speed of Falling Object

- Potential energy is converted to kinetic energy
- \( \frac{1}{2}mv^2 = mg\Delta h \)
- \( v = \sqrt{2gh}\Delta h \)
Conservation of Energy

- Learning Goals
  - Explain the relationship between work and energy.
  - Define and distinguish *kinetic* and *potential* energies.
- Questions: 12 - 18
- Exercises: 17, 19

Power

- Power is the time rate of doing work
  - More power, more work for given time.
  - More power, fixed amount of work in shorter time.
  - \( P = \frac{W}{t} \)
  - \( P = \frac{F d}{t} \)
- Units of power the *watt*.
  - British – *horsepower*
- Units summarized in Table 4.3

Example

- A constant force of 150 N is used to push a student’s motorcycle 10 m along a flat road in 20 s. Calculate the power in watts.
  - \( F = 150 \, \text{N}; \, d = 10 \, \text{m}; \, t = 20 \, \text{s} \)
  - \( P = \frac{F d}{t} \)
  - \( P = \frac{(150)(10)}{20} = 75 \, \text{W} \)
Power

- Electric bill
- Kilowatt - hr
  - Unit of energy
  - \( E = P \times t \)
- Table 4-4 gives typical power consumption of typical household appliances.

Power

- Learning Goals
  - Define Power and its units.
  - Distinguish between electrical power and electrical energy.
- Questions: 19 - 23
- Exercises: 21-25 odd

Forms of Energy and Consumption

- Must understand that all energy is conversion from one form to another!
  - Heat energy
  - Gravitational potential energy
  - Electrical energy
  - Chemical energy
  - Radiant energy
  - Nuclear energy
Conservation of Energy

- First law of Thermodynamics
  - Energy cannot be created or destroyed
  - The total amount of energy in the universe is constant
- Why doesn’t a pendulum keep swinging?
  - Friction
  - Changes the energy to heat energy

Forms of Energy and Consumption

- Fossil fuels
  - coal
  - oil
  - gas
- Alternative Fuels
  - Hydroelectric
  - Ethanol
  - Wind
  - Solar
    - Steam generation
    - Direct conversion (Solar cells)

Forms of Energy and Consumption

- Steam generation
- Direct conversion (Solar cells)
Forms of Energy and Consumption

Learning Goals
- Identify some common forms of energy
- Compare the main sources of energy and the main sources of energy consumption.
- List some ‘alternative’ energy sources and explain their pros and cons.

Questions: 24 - 27

Alternative and Renewable Energy Sources

Alternative energy sources
- NOT based on the burning of fossil fuels

Renewable energy sources
- Cannot be exhausted
- Much overlap between the two

Alternative/Renewable Sources

- Hydroelectric power
- Wind power
- Solar power
  - Photovoltaic
- Geothermal
- Tides
- Biofuels
- Biomass
Alternative and Renewable Energy Sources

Questions: 28 – 30

Key Terms: Matching, Multiple Choice, and Fill-in-the-Blank Questions; Visual Connection and Applying your Knowledge

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