Energy Transfer, PE, KE and Efficiency

ENERGY

• Part of our everyday lives:
  – Energetic people
  – Food that is “full of energy”
  – High cost of electric energy
  – Risks of nuclear energy
• Energy:
  – An ability to accomplish change
  • When anything happens in the physical world, energy is somehow involved.

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Work

• Definition:
  – A measure of the change a force produces:
  – “The work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance through which the force acts”.

\[ W = Fd \]
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Work

- Work is done…
  - …by a force when the object it acts on moves when the force is applied.
  - NO work is done by pushing against a stationary wall.
  - Work IS done throwing a ball because the ball MOVES while being pushed during the throw.
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Work

- Equation for work:

\[ w.d. = F \times d \]

- In words:

- Work Done = Force \times Distance through which the force acts

- The direction of the force (F) is assumed to be the same as the direction of the distance (d)

- A force perpendicular to the direction of motion of an object cannot do work on the object
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The Joule

• joule (J)
  – The SI unit of work
  • Amount of work done by a force of one Newton when it acts through a distance of one meter:

1 Joule = 1 Newton-metre

• Example:
  – Push a box 8 m across the floor with a force of 100 N (22.5 lbs) performs 800 J of work:

\[ W = Fd = (100N)(8m) = 800N \cdot m = 1J \]
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**Direction of Force**

- When a force and the distance through which it acts are parallel, the work done is equal to the product of $F$ and $d$.
- If the forces are NOT parallel, work done is equal to the product of $d$ and the projection of $F$ in the direction of $d$. 

$W = Fd$ 

$W = F_d d$
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Power

- The RATE of Doing Work…
  - Rate is the amount of work done in a specified period of time
  - The more powerful something is, the faster it can do work

\[ \text{Power} = P = \frac{W}{t} = \frac{\text{work done}}{\text{time interval}} \]
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Units of Power

- Standard (SI) unit of power is the watt

\[ 1 \text{ watt (W)} = 1 \text{ joule/second (J/s)} \]

- Example:
  - 500W motor can perform 500J of work
  - ... or 250J of work in 0.5 s
  - ... or 5000J of work in 10 s

- Watts are very small units
  - Kilowatts are used most commonly

\[ 1 \text{ kilowatt} = 1000W \]
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Energy

- Definition:
  - Energy is that property something has that enables it to perform work
    - If something has energy, it is able (directly or indirectly) to exert a force on something else and perform work.

- Types of Energy
  - Kinetic – Energy of Motion
  - Potential – Energy of Position

- Energy cannot be created or destroyed only transferred from one or to another
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Energy Transfer and Transformations

Total energy or work or power in

Machine

Useful energy or work or power out

Non-useful energy or work or power out
(usually heat)
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Energy Transfer and Transformations

Total energy or work or power in

Machine

Useful energy or work or power out

Non-useful energy or work or power out (usually heat)

Light Bulb
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Energy Transfer and Transformations

Total energy or work or power in

Machine

Useful energy or work or power out

Non-useful energy or work or power out (usually heat)

Electrical energy or power in

Light Bulb

Light energy or power out

Non-useful heat energy or power out

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Energy Transfer and Transformations

Total energy or work or power in

Machine

Useful energy or work or power out

Non-useful energy or work or power out (usually heat)

Electrical energy or power in

Light Bulb

Light energy or power out

Non-useful heat energy or power out

Loudspeaker

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Energy Transfer and Transformations

Total energy or work or power in → Machine → Useful energy or work or power out

Electrical energy or power in → Light Bulb → Light energy or power out

Electrical energy or power in → Loudspeaker → Sound energy or power out

Useful energy or work or power out

Non-useful energy or work or power out (usually heat)

Non-useful heat energy or power out

Non-useful heat energy or power out
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Energy Transfer and Transformations

Microphone
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Energy Transfer and Transformations

Sound energy or power in → Microphone → Useful electrical energy or power out

Non-useful heat energy or work or power out

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Energy Transfer and Transformations

Sound energy or power in

Microphone

Useful electrical energy or power out

Non-useful heat energy or work or power out

Generator
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Energy Transfer and Transformations

Sound energy or power in

Microphone

Useful electrical energy or power out

Non-useful heat energy or work or power out

Generator

Electrical energy out

Non-useful heat and sound energy or power out

Kinetic energy in
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Energy Transfer and Transformations

Sound energy or power in

Microphone

Useful electrical energy or power out

Non-useful heat energy or work or power out

Kinetic energy in

Generator

Electrical energy out

Non-useful heat and sound energy or power out

Spring

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Energy Transfer and Transformations

Sound energy or power in → Microphone
- Useful electrical energy or power out
- Non-useful heat energy or work or power out

Kinetic energy in → Generator
- Electrical energy out
- Non-useful heat and sound energy or power out

Kinetic energy in → Spring
- Strain potential energy out
- Non-useful heat and sound energy out

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Kinetic Energy

- Every moving object has the capacity to do work
  - Moving objects can exert forces on other moving or stationary objects
  - Kinetic energy depends on the mass and speed of a moving object

\[
KE = \frac{1}{2} mv^2
\]

Note that \(v^2\) factor means that \(KE\) increases VERY rapidly with increasing speed
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Kinetic Energy

• Variation of equation for acceleration
  – Example
    • Kinetic energy of a 1000kg car moving at 10 m/s is 50kJ
    • 50kJ of work must be done to start the car from a stop, or stop it when it is moving

\[ m = 1,000 \text{ kg}, \nu = 10 \text{ m/s}, \text{KE} = 50,000 \text{ J} \]

\[ m = 1,000 \text{ kg}, \nu = 30 \text{ m/s}, \text{KE} = 450,000 \text{ J} \]
When a hammer strikes a nail, the hammer’s kinetic energy is converted into work, which pushes the nail into the wood.
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Force on a Nail

- Example:
  - Using a hammer with a 600g head to drive a 5mm nail into a piece of wood, what is the force exerted on the nail on impact?

\[ \frac{1}{2}mv^2 = Fd \]

\[ F = \frac{mv^2}{2d} = \frac{(0.6\text{kg})(4\text{m/s})^2}{2(0.005\text{m})} = 960\text{N} = 216\text{lbs} \]
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Potential Energy

• The Energy of Position
  – When a stone is dropped, it falls (accelerates) towards the ground, until it hits the ground
    • If the ground is soft, the stone will make a small depression in the ground
  – In its original position, the stone had the capacity to do work, even though it is not moving and has no kinetic energy.
When a stone is held above the ground, it has POTENTIAL ENERGY because if it is dropped, it can do work on the ground (making the hole...

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Gravitational Potential Energy

- Determining PE of something near the earth’s surface

\[ W = Fd = mgh \]

Work (force/distance) = (weight/height)

Potential energy = PE = \( mgh \)
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Potential Energy Example

- Potential energy of a car pushed off a 45m cliff
- Compare with amount of KE done by a car moving at 30m/s

\[ PE = mgh = (1000kg)(9.8m/s^2)(45m) = 441kJ \]

\[ m = 1,000 \text{ kg}, \; v = 30 \text{ m/s}, \; KE = 450,000 \text{ J} \]

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Examples of Potential Energy

Examples are almost everywhere

- Book on the table
- Skier on the top of a slope
- Water at the top of a waterfall
- Car at the top of a hill
- A stretched spring
- A nail near a magnet

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Potential Energy is Relative

- Gravitational PE depends on the level from which it is measured…
  - Book dropped onto table
  - Book raised over head and dropped to floor
- “True” gravitational PE??
  - Gravitational PE is relative
  - Difference between two PE values is important because…
    - …this difference can be converted from PE to KE.
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Potential Energy is Relative

• Amount of potential energy is a function of the relative height of the objects
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Energy Transformations

- Most mechanical processes involve conversions between KE, PE, and work
  - A car rolling down a hill into a valley
    - PE at the top of the hill is converted into KE as the car rolls down the hill
    - KE is converted to PE as the car rolls up the other side
  - Total amount of energy (KE+PE) remains constant
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Energy Transformations

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Other Forms of Energy

- Chemical Energy
  - Gasoline converted to energy in a car
  - Food converted to energy in our bodies
- Heat Energy
  - Heat from burning coal or oil to make steam to drive power turbines
- Electric Energy
  - Electricity turns motors in homes and factories
- Radiant Energy
  - Energy from the sun
    - Evaporates water to form clouds
    - Provides plants with energy to grow
    - Creates temperature differences that make the wind blow
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Conservation of Energy

• Fundamental Law of Nature
  – Potential energy
    • Skiing down a hill – What happened to PE that the skier had at the top of the hill?
    • Driving a car, but shutting off the engine and coasting to a stop – What happened to the KE that the car had while moving
  – Energy is never lost, but it can be converted from one form to another

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Conservation of Energy

• The Law of Conservation of Energy:
  – Energy cannot be created or destroyed, although it can be changed from one form to another.
  • This principle has the widest application to all science
  • Applies equally to distant stars and biological processes in living cells.
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Energy Demand and Type

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The Energy Problem

- Limited Supply, Unlimited Demand
  - The sun – source of most of our energy
  - Food, wood, plants
  - Water power – The hydrological cycle
  - Wind power – Temperature changes
  - Fossil Fuels
    - Originally plants and animals dependent on the sun
  - Nuclear and hydrothermal power
    - Not related to the sun

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Solar Cells

- Variation due to climate and latitude
- £100/watt in 1960, £10/watt today
- Economics still limit widespread application
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Fossil Fuels

- Limited Supply
  - Most large deposits of oil and gas found
  - Remaining reserves = 100 years??
  - No new deposits being formed
- Problems with coal
  - Mining needed to extract from earth
  - Air pollution – dangerous to health
- All Fossil Fuels
  - Adds CO$_2$ to atmosphere – greenhouse effect
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Hydroelectric Power

• Kinetic energy of falling water converted into electricity using turbines
  – New hydro projects unlikely due to environmental and land-use constraints
  – Two-sided arguments
    • Environmental concerns
    • Development concerns

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Wind Energy

- Advantages
  - Non-polluting
  - Don’t contribute to global warming
  - Renewable resource

- Disadvantages
  - Only work where winds are powerful and reliable
  - Take up a lot of space
  - Noisy, some environmental concerns
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Other Energy Sources

- Geothermal Energy
- Nuclear Energy
- Tidal Energy

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Future Energy Supplies

• Fusion Energy
  – Technology may be many years into the future
• Most alternate energy sources are very expensive
  – Cost of fossil fuels is still the lowest and easiest to distribute

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Efficiency and Energy Transfer

Total energy or work or power in

Machine

Useful energy or work or power out

Non-useful energy or work or power out
(usually heat)
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Efficiency and Energy Transfer

Total energy or work or power in → Machine → Useful energy or work or power out

Electrical energy or power in → Light Bulb → Light energy or power out

Non-useful energy or work or power out (usually heat)
Non-useful heat energy or power out
Efficiency and Energy Transfer

Total energy or work or power in

Machine

Useful energy or work or power out

Non-useful energy or work or power out (usually heat)

Electrical energy or power in

Light Bulb

Light energy or power out

Non-useful heat energy or power out

100W or 100J/s

Light Bulb

60W or 60 J/s

40W or 40 J/s

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Efficiency and Energy Transfer

100W or 100J/s

Light Bulb

60W or 60 J/s

40W or 40 J/s

Efficiency = \text{useful energy/work/power out} \times 100 \% \over \text{total energy/work/power in}

Efficiency of light bulb = \frac{60 \times 100 \%}{100} = 60 \%