Work, Energy and Efficiency

Name: ANSWERS

Answer all questions on file paper.

Potential Energy

1. Define 'potential energy'. Include an appropriate example and the formula.
2. What is the potential energy possessed by a 50 kg person standing on a 3.2 m diving platform?
3. If a crate of mass 9 kg is lifted 1.5 m above the ground onto the back of a truck, calculate the increase in gravitational potential energy of the crate.
4. A rocket of mass 25 kg reaches a height of 500 m above the ground before it falls back to Earth. What is its maximum potential energy?
5. A drum of mass 80 kg is rolled up a ramp to a height of 2.3 m above the ground. What is its gain in gravitational potential energy?

Kinetic Energy

1. Define 'kinetic energy'. Include an appropriate example and the formula.
2. Calculate the kinetic energy of a 50 kg person running with a velocity of 5 m/s.
3. What is the kinetic energy of a bullet of mass 2 g travelling at a velocity of 750 m/s?
   [Hint: Convert g to kg!]
4. Which car has greater kinetic energy:
   a 1 000 kg car travelling at 18 m/s; or
   a 2 000 kg car travelling at 9 m/s?
5. Find the velocity of a 5 000 kg plane flying with 250 000 J of kinetic energy.
   [Hint: Use $v = \sqrt{\frac{2\text{KE}}{m}}$]

Work

1. Define 'work'. Include an appropriate example and the formula.
2. How much work is done when a 300 g pencil case is lifted to a desk 1.3 m high?
   [Hint: Convert g to kg!]
3. Find the work done when a box is pushed a distance of 18 m over a rough surface of frictional resistance 30 N.
4. An oil drum is rolled along a smooth surface for a distance of 25 m with a force of 18 N. How much work has been done?
5. Three people try to push a bogged car out of the mud, but the car does not move. Each person applies a force of 500 N. How much work was done? Explain your answer.

Work and Energy

1. State the law of conservation of energy.
2. How much work is required to lift a bag of wheat that is 50 kg to a height of 1.8 m?
3. A forklift raises crates of mass 600 kg a height of 3 m. How much work is done?
4. A 3 kg rock rolls down a hill at 3 m/s. How much work must be done to stop the rock?
   [Hint: All the KE must be removed from the rock.]
5. How much work must be done to stop a 1 200 kg car travelling at 10 m/s?
6. How much work is done when a 0.5 kg ball is thrown at 7 m/s?

Energy Transformations

1. A gas stove converts chemical energy to useful heat energy but it also produces some waste light energy. If a gas stove produced 4000 J of useful heat energy and 2000 J of waste light energy, how much chemical energy did it use?
2. A battery converts chemical energy to useful electrical energy but it also produces some waste heat energy. If a battery produced 1000 J of useful electrical energy and 300 J of waste heat energy, how much chemical energy did it use?
3. A blender converts electrical energy to useful mechanical energy but it also produces some waste sound energy. If a blender used 3000 J of electrical energy and produced 800 J of waste sound energy, how much useful mechanical energy was produced?
4. An apple falling from a tree converts gravitational energy to useful mechanical energy but it also produces some waste heat energy. If an apple used 1000 J of gravitational energy and produced 50 J of waste heat energy, how much useful mechanical energy was produced?

Efficiency

1. Can an ‘energy converter’, a device that changes stored energy to a more useful form, ever be 100% efficient? Explain.
2. Calculate the efficiency of the following:
   a. A solar cell that transforms 300 J of light energy into 45 J of electrical energy and 255 J of wasted energy.
   b. A wind turbine that transforms 500 J of kinetic energy in the wind to 150 J of electrical energy and 350 J of wasted heat and sound energy.

Potential Energy

1. Stored energy. E.g. lifting any mass above the ground transfers gravitational PE to it

$PE = mgh$, m = mass, kg
g = 9.80 m/s^2, acceleration due to gravity on Earth
h = height above the ground, m
PE = potential energy, J

2. $m = 50 kg$
$h = 3.2 m$
$g = 9.80 m/s^2$

$PE = mgh$
$= 50 \times 9.80 \times 3.2$
$= 1568 J$
$= 1.57 kJ$

3. $m = 9 kg$
$h = 1.5 m$
$g = 9.80 m/s^2$

gain in $PE = mgh$
$= 9 \times 9.80 \times 1.5$
$= 132.3 J$
$= 0.132 kJ$

4. $m = 25 kg$
$h = 500 m$
$g = 9.80 m/s^2$

max $PE = mgh$
$= 25 \times 9.80 \times 500$
$= 122\,500 J$
$= 123 kJ$

5. $m = 80 kg$
$h = 2.3 m$
$g = 9.80 m/s^2$

gain in $PE = mgh$
$= 80 \times 9.80 \times 2.3$
$= 1803.2 J$
$= 18.0 kJ$

Kinetic Energy

1. Energy of motion. Any moving object (mass) has KE.

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

m = mass, kg
v = velocity, m/s
KE = kinetic energy, J

2. $m = 50 kg$
$v = 5 m/s$

$KE = \frac{1}{2}mv^2$
$= 0.5 \times 50 \times 5^2$
$= 625 J$

3. $m = 2 g$ (÷ 1000)
$= 0.002 kg$
$v = 750 m/s$

$KE = \frac{1}{2}mv^2$
$= 0.5 \times 0.002 \times 750^2$
$= 563 J$

4. $m = 1000$ kg, $v = 18$ m/s

$KE = \frac{1}{2}mv^2$
$= 0.5 \times 1000 \times 18^2$
$= 162\,000$ J
$= 162$ kJ

$m = 2000$ kg, $v = 9$ m/s

$KE = \frac{1}{2}mv^2$
$= 0.5 \times 2000 \times 9^2$
$= 81\,000$ J
$= 81$ kJ

∴ The car with twice the velocity has more KE. Note that because velocity is squared in the formula, it has a greater effect on KE than mass.

5. $m = 5000$ kg
$KE = 250\,000$ J
$v = ?$

$v = \sqrt{\frac{2KE}{m}}$
$= \sqrt{\frac{2 \times 250\,000}{5000}}$
$= 10$ m/s

Work

1. Work is done when a force moves a mass through a distance. E.g. Work is done against gravity to lift a mass.

$$Work = Fd$$

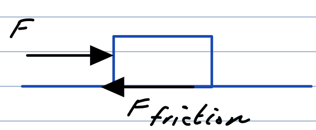
F = force, N
d = distance, m
Work = work done, J

2. $m = 300$ g $(\div 1000)$
$= 0.300$ kg
$h = 1.3$ m
$g = 9.80$ m/s^2

Work done = gain in PE
$= mgh$
$= 0.300 \times 9.80 \times 1.3$
$= 3.82$ J

3. $d = 18$ m
$F = 30$ N

Work $= Fd$
$= 30 \times 18$
$= 540$ J



Note: The force required to push the box must be equal to the amount of friction.

4. $d = 25$ m
$F = 18$ N

Work $= Fd$
$= 18 \times 25$
$= 450$ J

Note: Because there is no friction, this is an unbalanced force and the mass will be accelerating!

5. No work is done. Even though each person is exerting a force, the mass (car) isn't moving. Therefore, by definition, since $d = 0$, Work = Fd = zero!

Work and Energy

1. The law of conservation of energy states that energy cannot be created or destroyed, only transferred or transformed.

2. $m = 50 kg$, $h = 1.8 m$, $g = 9.80 m/s^2$

Work done = gain in PE
= mgh
= $50 \times 9.80 \times 1.8$
= **882 J**

3. $m = 600 kg$, $h = 3 m$, Work = ?, $g = 9.80 m/s^2$

Work done = gain in PE
= mgh
= $600 \times 9.80 \times 3$
= **17640 J**

4. $m = 3 kg$, $v = 3 m/s$

Work done = loss in KE
= $\frac{1}{2} m v^2$
= $0.5 \times 3 \times 3^2$
= **13.5 J**

5. $m = 1200 kg$, $v = 10 m/s$

Work done = loss in KE
= $\frac{1}{2} m v^2$
= $0.5 \times 1200 \times 10^2$
= **60000 J**

6. $m = 0.5 kg$, $v = 7 m/s$

Work done = gain in KE
= $\frac{1}{2} m v^2$
= $0.5 \times 0.5 \times 7^2$
= **12.25 J**

Energy Transformations

1. 4000 J heat + 2000 J light = **6000 J chemical energy**
2. 1000 J electricity + 300 J heat = **1300 J chemical energy**
3. mechanical energy = 3000 J electrical − 800 J sound = **2200 J**
4. mechanical energy = 1000 J GPE − 50 J heat = **950 J**

Efficiency

1. No energy converter can ever be 100% efficient because some energy is always lost, usually as heat (and sound).

2\. a) $\% \text{ eff} = \frac{\text{useful out}}{\text{total in}} \times 100$

$= \frac{45}{300} \times 100$

$= 15\%$

b) $\% \text{ eff} = \frac{\text{useful out}}{\text{total in}} \times 100$

$= \frac{150}{500} \times 100$

$= 30\%$