AS Level Physics

Chapter 4 – Work, Energy and Power

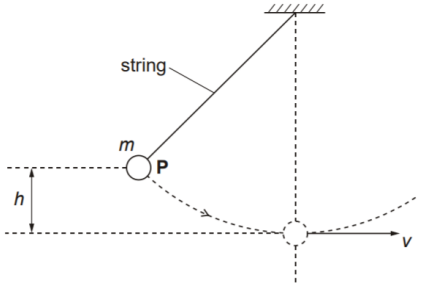
4.2.2 Kinetic and Potential Energies

Worked Examples

KE AND GPE EXCHANGE

Exam Style Question 1:

The figure below shows a simple pendulum with a metal ball attached to the end of a string.



When the ball is released from P, it describes a circular path. The ball has a maximum speed v at the bottom of its swing. The vertical distance between P and bottom of the swing is h. The mass of the ball is m.

i) Write the equations for the change in gravitational potential energy, E_p, of the ball as it drops through the height h and for the kinetic energy, E_k, of the ball at the bottom of its swing when travelling at speed v.

ii) Use the principle of conservation of energy to derive an equation for the speed v. Assume that there are no energy losses due to air resistance.

KE AND GPE EXCHANGE

Exam Style Question 1:

Answer:

i) Write down equations for the change in gravitational potential energy and kinetic energy of the ball:

$$E_p = mgh$$

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

ii) Derive an equation for speed:

As we are assuming that there are no energy losses and we are using the principle of conservation of energy all the GPE lost is converted into the KE gained and vice versa. Therefore:

$$GPE = KE$$

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

Cancel out the masses

$$gh = \frac{1}{2}v^2$$

Rearrange for v^2

$$v^2 = 2gh$$

$$\therefore v = \sqrt{2gh}$$

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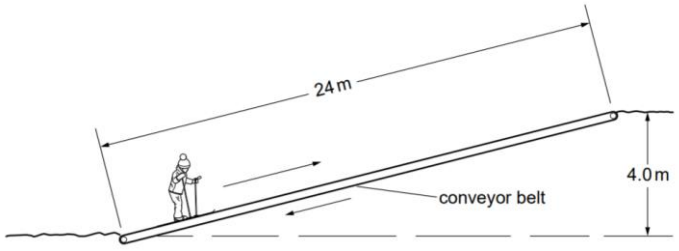
KE AND GPE EXCHANGE

Exam Style Question 2:

The figure below illustrates a conveyor belt for transporting young children up a snow-covered bank so that they can ski back down.



A child of mass $20\ kg$ travels up the conveyor belt at a constant speed. The distance travelled up the slope is $24\ m$ and the time taken is $55\ s$. The vertical height climbed in this time is $4.0\ m$.

For the child on the conveyor belt, calculate:

a) Her speed,

b) Her kinetic energy,

c) The increase in her potential energy for the complete journey up the slope.

KE AND GPE EXCHANGE

Exam Style Question 2:

Answer:

a) Calculate her speed:

Simply use: $speed = \frac{distance}{time}$

$$s = \frac{24\ m}{55\ s}$$

Therefore, her speed is $0.436\ m\ s^{-1}$.

b) Calculate her kinetic energy:

Use: $KE = \frac{1}{2}\ m\ v^2$

$$KE = \frac{1}{2} \times 20\ kg \times (0.436 \ldots m\ s^{-1})^2 = 1.9\ J$$

Therefore, her KE is $1.9\ J$.

c) Calculate her increase in potential energy:

$$PE = m\ g\ h$$
$$PE = 20\ kg \times 9.81\ m\ s^{-2} \times 4\ m$$
$$PE = 784\ J$$

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KE AND GPE EXCHANGE

Exam Style Question 3:

a) An object falling towards the ground has both KE and GPE. Explain what is meant by GPE without using an equation.

b) A ball of mass $0.20\ kg$ is thrown vertically downwards at a speed of $15\ m\ s^{-1}$ towards the ground from a height of $2.8\ m$. The ball hits the ground and rebounds at a speed of $12\ m\ s^{-1}$, as shown in Fig. 4.1. Assume air resistance has negligible effect on the motion of the ball.

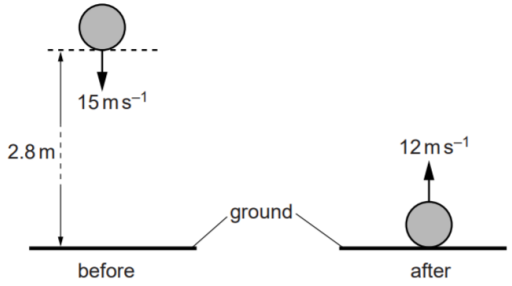

Fig. 4.1

i) Calculate the speed of the ball just before it hits the ground.

ii) Calculate the energy transferred to the ground during the impact.

iii) The time of impact of the ball with the ground is $0.065\ s$.

Calculate the magnitude of the average force exerted by the ground on the ball during the impact.

KE AND GPE EXCHANGE

Exam Style Question 3:

Answer:

a) Explain what is meant by GPE:

GPE is the energy an object has by virtue of its position above the surface of the Earth.

bi) Calculate the speed of the ball just before it hits the ground:

Here you will have to use the SUVAT equation:

$$v^2 = u^2 + 2as$$
$$v^2 = (15^2) + 2(9.81)(2.8)$$
$$v^2 = 279.936$$
$$v = \sqrt{279.936}$$
$$v = 16.7\ m\ s^{-1}$$

Therefore, the speed of the ball just before it hits the ground is $16.7\ m\ s^{-1}$.

bii) Calculate the energy transferred to the ground during the impact:

$$KE_{before\ impact} = \frac{1}{2} \times 0.20\ kg \times (16.73\ \ldots\ m\ s^{-1})^2 = 27.9936\ J$$
$$KE_{after\ impact} = \frac{1}{2} \times 0.20\ kg \times (12)^2 = 14.4\ J$$
$$Energy\ lost = 27.9936 - 14.4 = 13.5936\ J$$

Therefore, the energy transferred to the ground during the impact is $14\ J$.

biii) Calculate the magnitude of the average force exerted by the ground on the ball during the impact.

Step 1: Use the formula $F = ma$

Step 2: Calculate the acceleration of the ball:

$$a = \frac{v - u}{t} = \frac{12\ m\ s^{-1} - (-16.7\ m\ s^{-1})}{0.065\ s} = \frac{28.7\ m\ s^{-1}}{0.065\ s}$$

Step 3: Calculate the force:

$$F = ma = (0.20\ kg)\left(\frac{28.7\ m\ s^{-1}}{0.065\ s}\right) = 88\ N$$

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KE AND GPE EXCHANGE

Exam Style Question 4:

a) State the principle of conservation of energy.

b) Fig 6.1 shows a glider on a horizontal frictionless track.

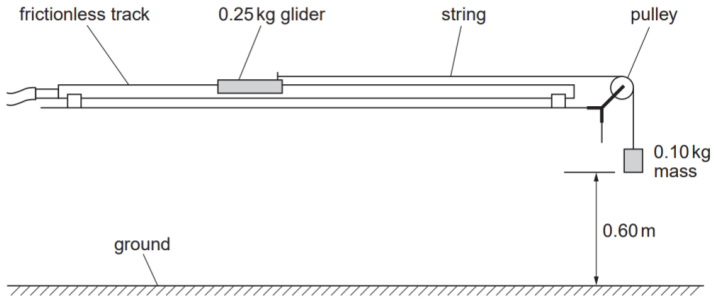

Fig. 6.1

The mass of the glider is $0.25\ kg$. One end of a string is fixed to the glider and the other end to a $0.10\ kg$ mass. The $0.10\ kg$ mass is held stationary at a height of $0.60\ m$ from the ground. The pulley is more than $0.60\ m$ away from the front of the glider. When the $0.10\ kg$ mass is released, the glider has a constant acceleration of $2.8\ m\ s^{-2}$ towards the pulley. The $0.10\ kg$ mass instantaneously comes to rest when it hits the ground.

i) Calculate the loss in potential energy of the $0.10\ kg$ mass as it falls through the distance of $0.60\ m$.

ii) The glider starts from rest. Show that the velocity of the glider after travelling a distance of $0.60\ m$ is about $1.8\ m\ s^{-1}$.

iii) Calculate the kinetic energy of the glider at this velocity of $1.8\ m\ s^{-1}$.

iv) Explain why the answer to (b)(iii) is not the same as (b)(i).

KE AND GPE EXCHANGE

Exam Style Question 4:

Answer:

a) State the principle of conservation of energy:

Energy can neither be created nor destroyed but it can be transformed from one form to another.

bi) Calculate the loss in potential energy:

It is a loss in PE because the mass is falling from a higher position to a lower position.

Use: $PE = mgh$

$$loss\ in\ PE = 0.10\ kg \times 9.81\ m\ s^{-2} \times 0.60\ m$$
$$loss\ in\ PE = 0.59\ J$$

bii) Show that the velocity of the glider is about $1.8\ m\ s^{-1}$:

Here we have to use SUVAT equation:

$$v^2 = u^2 + 2as$$
$$v^2 = 0^2 + 2(2.8\ m\ s^{-2})(0.60\ m)$$
$$v = \sqrt{2 \times 2.8 \times 0.60}$$
$$v = 1.833030278\ m\ s^{-1}$$
$$v = 1.8\ m\ s^{-1}$$

biii) Calculate the KE of glider at this velocity of $1.8\ m\ s^{-1}$:

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

$$KE = \frac{1}{2}(0.25\ kg)(1.8)^2$$
$$KE = 0.41\ J$$

biv) Explain why the answer to (b)(iii) is not the same as (b)(i).

KE of $0.10\ kg$ mass is not taken into account.

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KE AND GPE EXCHANGE

Exam Style Question 5:

A granite block is suspended at rest just below the surface of water in a tank (Figure i). The block is now released and falls $0.80\ m$ to the bottom (Figure ii).

Figure (i)

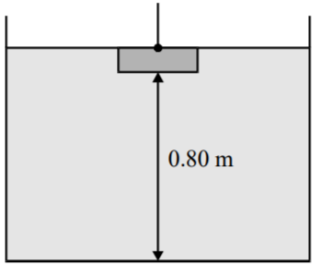
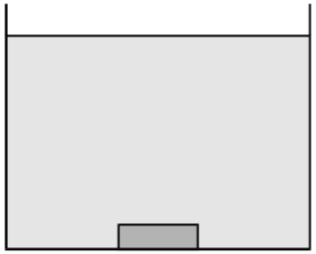


Figure (ii)



a) The volume of the block is $3.0 \times 10^{-3}\ m^3$, and the density of granite is $2700\ kg\ m^{-3}$. Calculate the gravitational potential energy lost by the block as it falls.

b) Although the water level has not changed, the water has gained GPE. Explain why.

c) The GPE gained by the water is less than that lost by the granite block. Explain this.

KE AND GPE EXCHANGE

Exam Style Question 5:

Answer:

a) Calculate the GPE lost by the block as it falls:

Step 1: Use $density = \frac{mass}{volume}$ to calculate the mass of the block.

$$mass = density \times volume$$

$$mass = (2700\ kg\ m^{-3}) \times (3.0 \times 10^{-3}\ m^3)$$

$$m = 8.1\ kg$$

Step 2: Use $GPE = mgh$ to calculate the GPE lost.

$$GPE = mgh$$

$$GPE = (8.1\ kg)(9.81\ m\ s^{-2})(0.8\ m)$$

$$GPE = 63.5688\ J$$

Therefore, the GPE lost by the block is $64\ J$.

b) Although the water level has not changed, the water has gained GPE. Explain why.

As the block falls within the tank some of the water is displaced and as the block falls some of the water moves up.

c) The GPE gained by the water is less than that lost by the granite block. Explain this.

Some energy is dissipated and lost to the surroundings by being converted from one form to another such as sound, heat, internal energy or KE.

Please see ‘4.2.1 Kinetic and Potential Energies notes’ pack for revision notes.

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