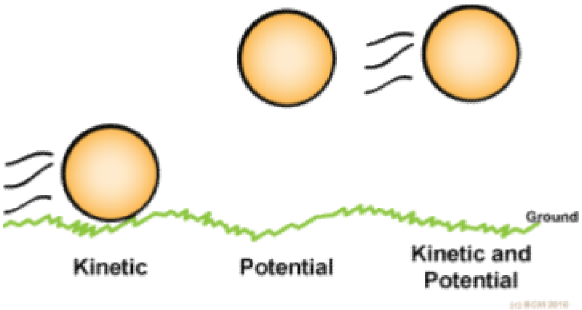
Name: Class:

Total Possible Marks: 20

Kinetic and Potential Energy



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1. Anything that is moving has energy in its kinetic energy store. Energy is transferred to this store when an object speeds up and is transferred away from the store when an object slows down. The energy in the kinetic energy store depends on the object's mass and speed.

The equation for kinetic energy is:

$$KE = 1/2\ mv^2$$

Where 'm' is the mass in kilograms, and 'v' is the velocity in metres per second.

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a) A motor vehicle with a mass of 1250 kg is moving at 22 m/s. Calculate the kinetic energy in its kinetic energy store.

Using the equation above we have KE = 1/2 x 1250 x 22 x 22 = 302,500 J

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b) A motorcycle holds 1.17×10^4 J in its kinetic energy store. The motorcycle is moving along at 12 m/s, what is the mass of the motorcycle in kilograms?

This time you need to rearrange the equation in terms of mass, so m = $(2KE/v^2)$. Once you have completed this rearrangement, enter the values that you know to calculate the unknown quantity.

Mass= $(2 \times 1.17 \times 10^4)/ 12^2$ = 162.5 kg

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c) The motorcycle in part (b) picks up the pillion passenger with a mass of 42 kg. The rider continues his journey and accelerates up to a constant speed of, once again, 12 m/s. Given this new information, calculate the new kinetic energy in the kinetic energy store.

The mass of the motorcycle has increased from 162.5 kg to 204.5 kg. Using the equation we now calculate the new kinetic energy value:

KE = 1/2 x 204.5 x 12 x 12 = 14,724 J or to express this in scientific notation as the original value was given in part (b) = 1.4724×10^4 J

10 2. A science student has a mass of 85 kg. He runs up some stairs carrying a 10 kg box. The staircase is 10 m high and it takes him 7 seconds to reach the top.

* Allocate one mark for the correct working and the second mark for the correct answer

2 a) How much energy has been transferred to the gravitational potential energy store of the student and the box when he reaches the top of the stairs?

Using the formula GPE = mgh and inserting the appropriate values for mass gravitational field strength and height:

GPE = (85 + 10) x 9.8 x 10 = 9310 J

* Allocate one mark for the correct working and the second mark for the correct answer

2 b) What is the power output of the student as he runs up the stairs?

Power output is work done divided by the time taken so the power output of the student would be 9310÷7 = 1330 W

* Allocate one mark for the correct working and the second mark for the correct answer

2 c) At the top of the stairs, the student walks along the corridor still carrying the box. Calculate the students velocity if the total energy in the kinetic energy store of the student and the box is 153.9 J. State your answer in metres per second.

Using the equation for kinetic energy:

KE = 1/2 mv^2 and rearranging to make v^2 the subject:

v^2 = 2 x KE / m = (2 x 153.9) / 95 = 3.24 so v = √3.24 = 1.8 m/s

* Allocate one mark for the correct working and the second mark for the correct answer

4 d) The student then stops and drops the box from a height of 1.25 m. Calculate the speed at which it hits the ground, stating any assumptions you may make. State your answer in metres per second to 2 significant figures

All of the gravitational potential energy is transferred to kinetic energy during the fall. At the moment before the box hits the ground it will have 122.5 joules of kinetic energy (from the GPE = 10 x 9.8 x 1.25 and the L.O.C.O.E.). By rearrangement of the equation for kinetic energy, we can calculate v^2 and then subsequently v.

v^2 = (2 x 122.5) / 10 = 24.5 therefore v = √24.5 = 4.9 m/s to 2 s.f.

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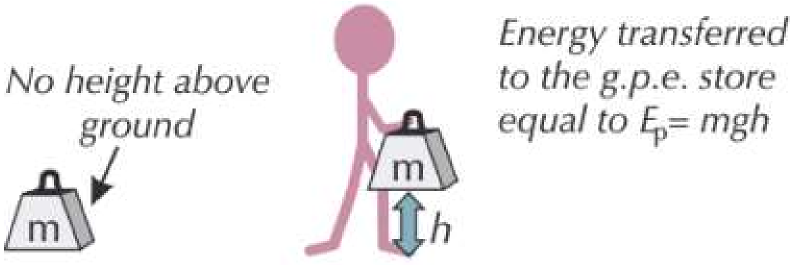

Lifting an object in a gravitational field requires work, this causes a transfer of energy into the objects gravitational potential energy store (sometimes simply referred to as potential energy or PE). The amount of energy transferred depends on the mass of the object, the distance through which it is lifted and the gravitational field force it is experiencing. On earth the gravitational field forces approximately 9.81 N per kilogram.

The formula to calculate gravitational potential energy is:

$$GPE\ (PE) = m \times g \times h$$

Where 'm' is the mass in kilograms, 'g' is the gravitational field strength in newtons per kilogram and 'h' is the height in metres.

1 a) A 50 kg mass is slowly raised through a height of 6 m, find the energy transferred to its gravitational potential energy stored. The gravitational field strength should be taken as 9.8 N per kilogram.

This is simply a matter of plugging the values in:

GPE = 50 x 9.8 x 6 = 2940 J

1 b) A flea of mass 1.0×10^{-3} g jumps vertically from the ground. The gravitational field strength is 9.8 N per kilogram. At the top of the jump the flea has gained 1.96×10^{-6} J of energy in its gravitational potential energy store. How high has the flea jumped?

First of all we need to rearrange the equation so that the 'h' unknown value is the subject, therefore if GPE = mgh then h = GPE/mg.

What we must remember is that the mass of the flea is given in grams whereas the equation expects a figure in kilograms, we must convert this before plugging values. We divide the mass of the flea by 1000 to express it in kilograms, this is 1.0×10^{-6} kg.

$h = 1.96 \times 10^{-6} / (1.0 \times 10^{-6} \times 9.8) = 0.20$m

2 4. A communications engineer with a mass of 125 kg stands at the top of the Eiffel Tower, making some repairs to the transmitters.

The Eiffel Tower stands at a height of 300 m but including the transmitters this rises to 324 m.

1 a) What is the gravitational potential energy stored in the man's GPE store? Take the gravitational field strength to be 9.81 N per kilogram.

397,305 J

1 b) When the engineer climbs down from the transmitters back to the 300 m point, how much gravitational potential energy has he lost (if any)

There are 2 ways to evaluate this, you can if you like workout the GPE in both situations and take the one from the other, or simply work out GPE for the difference in height. Given that GPE = mgh we can say:

GPE = 125 x 9.81 x (324 - 300) = 29, 430 J

2 5. Another energy store similar to gravitational potential energy is elastic potential energy. Stretching or squashing object for example a spring or a rubber ball can transfer elastic potential energy to the objects elastic potential energy store. The energy stored can be found using the equation:

$$E = 1/2\ ke^2$$

Where E is the elastic potential energy in Joules, 'e' is the extension in metres and 'k' is the spring constant in Newtons per metre

1 a) A spring with a spring constant of 40 N per metre is stretched from its normal length of 8 cm to a stretched length of 23 cm. Calculate the energy transferred to its elastic potential energy store.

This is quite a straightforward question, involving the insertion of given data into the formula... Having said this be mindful of the fact that the extension was given to you in centimetres, it needs to be converted into metres before it can be used!

$E = 1/2 \times 40 \times (0.23-0.08)^2 = 0.45$ J

1 b) A spring is stretched by 60 cm, which transfers 18 J of energy to the springs elastic potential energy store. What is the value of the spring constant?

This requires the manipulation of the equation so that the spring constant 'k' becomes the subject of the expression, again be mindful of any unit conversions necessary:

given the equation $E = 1/2\ ke^2$ we can rearrange this in terms of 'k':

$k = 2E/e^2$ which, when the correct values are inserted into the variables gives us $k = (2 \times 18) / (0.60)^2$ = 100 N per metre.

1 6. A construction worker is laying bricks at the top of a 200 m tall block of flats. Each brick weighs approximately 1.2 kg. As the worker goes to pick up a brick he accidentally knocks it, and it falls to the ground. Taking the value of 'g' to be 9.81 N per kilogram, calculate the speed at which the brick hits the ground.

To solve a problem like this you need to be aware of the law of conservation of energy. The brick holds a certain amount of gravitational potential energy before it starts to fall, but during the fall the gravitational potential energy is transferred to the bricks kinetic energy store. An instant before the brick hits the ground the gravitational potential energy will be at its minimum value and the potential energy at its maximum value. Assuming negligible air resistance and no other factors, the energy lost from the GPE equals the energy gained in the KE.

$$mgh = 1/2\ mv^2$$

We need to rearrange this expression to make v^2 the subject, after which we can take the square root to obtain the answer we want:

Given the above:

$$v^2 = 2gh$$

The 'm' has disappeared as it cancelled out on each side. All that you need to do now is enter the values you have and take the square root of the result:

$$v^2 = 2 \times 9.81 \times 200 = 3924 \text{ so } v = \text{sqrt}\ (3924) = 62.6\ ms^{-1}$$

(62.6 ms^{-1} is approximately 140 mph - ouch!)