Lesson 2 Gravitational potential energy

Learning drill (questions from the last topic, motion and forces0

1. What is the equation used to calculate speed?
2. What are the units of acceleration?
3. What are the units of speed?
4. Name a factor which affects thinking distance.
5. Name a factor which affects braking distance.
6. What is acceleration?
7. What is Newton’s second law?
8. What is the equation used to calculate acceleration?
9. What is a vector?
10. What is a scalar?

Gravitational potential energy

Lifting an object in a gravitational field requires work. This causes a transfer of energy to the gravitational potential energy (GPE) store of the raised object. When an object is at any height above the Earth’s surface, it will have energy in its gravitational potential energy store. The higher an object is lifted, the more energy is transferred to this store.

The amount of energy in an object’s GPE store depends on its mass, its height and the strength of the gravitational field the object is in. The amount of energy that is transferred to an object’s gravitational potential energy store when it’s raised through a certain height can be found by:

Change in gravitational potential energy = mass x gravitational field strength x height

$$∆GPE=m x g x h$$

Measured in Joules, J

Measured in metres, m

Measured in kilograms, kg

Measured in Newtons/kilograms, N/kg

On Earth, the gravitational field strength (g) is approximately 10 N/kg.

Gravitational field strength on different planets:

The larger the planet, the bigger the value of g

|  |  |
| --- | --- |
| Planet | Gravitational field strength, g (N/kg) |
| Mercury | 3.8 |
| Venus | 8.8 |
| Earth | 10 |
| Mars | 3.8 |
| Jupiter | 25 |
| Saturn | 10.4 |
| Uranus | 10.4 |
| Neptune | 13.8 |

Worked Example 1

A 50kg mass is slowly raised through a height of 6.0m. Find the energy transferred to its gravitational potential energy store. The gravitational field strength is 10N/kg.

m = 50kg

h = 6.0m

g = 10N/kg

GPE = m x g x h = 50 x 10 x 6 = 3000 J = 3 kJ

Worked example 2

A 25,000kg plane takes off and climbs to a height of 12,000m above its take off point. How much energy has been transferred to its gravitational potential energy store? g = 10N/kg

m = 25,000 kg

h = 12,000 m

g = 10 N/kg

GPE = m x g h = 25000 x 10 x 12000 = 3,000,000,000 J

Worked example 3

A person of mass 75kg climbs an unknown height and gains 3,750J of energy in their gravitational potential energy store. if the gravitational field strength, g = 10N/kg, calculate the height climbed by the person.

m = 75 kg

GPE = 3,750 J

g = 10 N/kg

GPE = m x g x h

$h= \frac{GPE}{m x g }= \frac{3750}{75 x 10}=5 m$

Worked example 4

A mass is lifted through 20m and gains 20,000J of energy in its gravitational potential energy store. Calculate the mass. The value of gravitational field strength, g = 10N/kg.

h = 20 m

GPE = 20000 J

g = 10 N/kg

GPE = m x g x h

$m= \frac{GPE}{g x h }= \frac{20000}{10 x 20}=100 kg$

Questions

Remember g = 10 N/kg

**Basic:**

1. What type of objects have gravitational potential energy?
2. What is the equation for gravitational potential energy?
3. What are the units for gravitational potential energy, mass, gravitational field strength and height?
4. Calculate the **gravitational potential energy** of the following objects on Earth:
5. m = 10 kg

h = 5 m

g = 10 N/kg

1. m = 20 kg
h = 15 m

g = 10 N/kg

1. m = 100 g (you must convert g into kg before you calculate EK)
h = 100 cm

g = 10 N/kg

1. If an object is raised 100m above ground with a mass of 100kg, how much **gravitational potential energy** did it gain?
2. If an object with a mass of 25kg is raised 10m how much **gravitational potential energy** did it gain?
3. A diving platform is 10 m above the ground. When an 80 kg diver climbs to the top of the platform, how much **GPE** does he acquire?

**Medium**: Rearranging needed

1. Rearrange the equation for GPE to give an equation for the **height**.
2. An object gains gravitational potential energy of 300J. If the mass of the object is 3kg, what is the **height** that the object has been raised?
3. If the GPE of an object is 1000J and the mass is 25kg, what is the **height** of the object?
4. What is the **height** of an object with a mass of 10kg and gravitational potential energy of 3500J?
5. Rearrange the equation for GPE to give an equation for **mass**.
6. What is the **mass** of an object when it is raised 25m and gains gravitational potential energy of 50 000J?
7. An object has a gravitational potential energy of 500 J and is located at a height of 20m above the ground. Calculate the **mass** of the object.
8. Calculate the **mass** of an object that has a gravitational potential energy of 250 J and is up at a height of 20 cm.

**Hard:** Rearranging and unit conversion needed

1. A rocket is stationary at a height of 3000 m; its gravitational potential energy is 300 kJ, what is its **mass**?
2. A skier, with a mass of 70 kg, loses 140 kJ of energy when skiing down the slope. What was the **height** which the skier descended.
3. 2 J of GPE are lost by a 50 g conker which falls from a tree. How **high** did it fall from?
4. A crane lifts a pallet of bricks to the top of a 80 m building, requiring 400 kJ of energy. What was the **mass** of the pallet?

Answers

Learning Drill

1. What is the equation used to calculate speed? $speed= \frac{distance}{time}$
2. What are the units of acceleration? m/s2
3. What are the units of speed? m/s
4. Name a factor which affects thinking distance. Speed, reaction time, tiredness, drugs, alcohol, distractions
5. Name a factor which affects braking distance. Speed, mass of the vehicle, worn brakes, how good the tyres are, state of the road (ice, water, fuel spillage)
6. What is acceleration? Acceleration is the rate of change of velocity (how quickly your velocity changes)
7. What is Newton’s second law? Force = mass x acceleration F = m x a
8. What is the equation used to calculate acceleration? $a= \frac{(v-u)}{t}= \frac{change in velocity}{time}$
9. What is a vector? A quantity that has both magnitude and direction.
10. What is a scalar? A quantity that has only magnitude.

**Basic:**

1. What type of objects have gravitational potential energy? Any object above the ground/ any object that could fall.
2. What is the equation for gravitational potential energy? GPE = m x g x h
3. What are the units for gravitational potential energy (Joules, J), mass (kilograms, kg), gravitational field strength (Newtons per kilogram, N/kg) and height (metres, m)?
4. Calculate the **gravitational potential energy** of the following objects on Earth:
5. m = 10 kg

h = 5 m

g = 10 N/kg

GPE = m x g x h = 10 x 10 x 5 = 500 J

1. m = 20 kg
h = 15 m

g = 10 N/kg

GPE = m x g x h = 20 x 10 x 15 = 3000 J

1. m = 100 g (you must convert g into kg before you calculate EK) = 0.1kg
h = 100 cm = 1m

g = 10 N/kg

GPE = m x g x h = 0.1 x 10 x 1 = 1 J

1. If an object is raised 100m above ground with a mass of 100kg, how much **gravitational potential energy** did it gain?

h = 100m

m = 100 kg

g = 10 N/kg

GPE = m x g x h = 100 x 10 x 100 = 100,000 J = 100 kJ

1. If an object with a mass of 25kg is raised 10m how much **gravitational potential energy** did it gain?

m = 25 kg

h = 10 m

g = 10N/kg

GPE = m x g x h = 25 x 10 x 10 = 2500J = 2.5kJ

1. A diving platform is 10 m above the ground. When an 80 kg diver climbs to the top of the platform, how much **GPE** does he acquire?

h = 10m

m = 80kg

g = 10N/kg

GPE = m x g x h = 80 x 10 x 10 = 8000J = 8kJ

**Medium**: Rearranging needed

1. Rearrange the equation for GPE to give an equation for the **height**.

$$h= \frac{GPE}{m x g }$$

1. An object gains gravitational potential energy of 300J. If the mass of the object is 3kg, what is the **height** that the object has been raised?

GPE = 300 J

m = 3kg

g = 10 N/kg

$h= \frac{GPE}{m x g }= \frac{300}{3 x 10}=10m$

1. If the GPE of an object is 1000J and the mass is 25kg, what is the **height** of the object?

GPE = 1,000J

m = 25kg

g = 10N/kg

$h= \frac{GPE}{m x g }= \frac{1000}{25 x 10}=4m$

1. What is the **height** of an object with a mass of 10kg and gravitational potential energy of 3500J?

m = 10 kg

GPE = 3500 J

g = 10N/kg

$h= \frac{GPE}{m x g }= \frac{3500}{10 x 10}=35m$

1. Rearrange the equation for GPE to give an equation for **mass**.

$$m= \frac{GPE}{g x h}$$

1. What is the **mass** of an object when it is raised 25m and gains gravitational potential energy of 50 000J?

h = 25 m

GPE = 50,000 J

g = 10N/kg

$$m= \frac{GPE}{g x h}= \frac{50000}{10 x 25}=200 kg$$

1. An object has a gravitational potential energy of 500 J and is located at a height of 20m above the ground. Calculate the **mass** of the object.

GPE = 500 J

h = 20m

g = 10 N/kg

$$m= \frac{GPE}{g x h}= \frac{500}{10 x 20}=2.5 kg$$

1. Calculate the **mass** of an object that has a gravitational potential energy of 250 J and is up at a height of 20 cm.

GPE = 250 J

h = 20 cm = 0.2m

g = 10N/kg

$$m= \frac{GPE}{g x h}= \frac{250}{10 x 0.2}=125 kg$$

**Hard:** Rearranging and unit conversion needed

1. A rocket is stationary at a height of 3000 m; its gravitational potential energy is 300 kJ, what is its **mass**?

h = 3000m

GPE = 300kJ = 300,000J

g = 10N/kg

$$m= \frac{GPE}{g x h}= \frac{300000}{10 x 3000}=10 kg$$

1. A skier, with a mass of 70 kg, loses 140 kJ of energy when skiing down the slope. What was the **height** which the skier descended.

m = 70kg

GPE = 140kJ = 140,000J

g = 10 N/kg

$h= \frac{GPE}{m x g }= \frac{140000}{70 x 10}=200m$

1. 2 J of GPE are lost by a 50 g conker which falls from a tree. How **high** did it fall from?

GPE = 2J

m = 50g = 0.05kg

g = 10N/kg

$h= \frac{GPE}{m x g }= \frac{2}{0.05 x 10}=4m$

1. A crane lifts a pallet of bricks to the top of a 80 m building, requiring 400 kJ of energy. What was the **mass** of the pallet?

h = 80m

GPE = 400 kJ = 400,000J

g = 10N/kg

$$m= \frac{GPE}{g x h}= \frac{400000}{10 x 80}=500 kg$$