CIRCULAR MOTION AND SHM : Higher Level Long Questions.

*****ALL QUESTIONS ARE HIGHER LEVEL******

Circular Motion

2012 Question 12 (a) (Higher Level)

An Olympic hammer thrower swings a mass of 7.26 kg at the end of a light inextensible wire in a circular motion. In the final complete swing, the hammer moves at a constant speed and takes 0.8 s to complete a circle of radius 2.0 m.

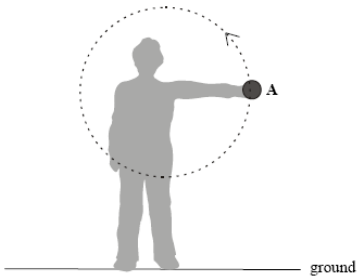
(i) What is the angular velocity of the hammer during its final swing?
(ii) Even though the hammer moves at a constant speed, it accelerates. Explain.
(iii) Calculate the acceleration of the hammer during its final swing
(iv) Calculate the kinetic energy of the hammer as it is released.

2011 Question 6 (*c*) (Higher Level)

A simple merry-go-round consists of a flat disc that is rotated horizontally.
A child of mass 32 kg stands at the edge of the merry-go-round, 2.2 metres from its centre.
The force of friction acting on the child is 50 N.
Draw a diagram showing the forces acting on the child as the merry-go-round rotates.

What is the maximum angular velocity of the merry-go-round so that the child will not fall from it, as it rotates?
If there was no force of friction between the child and the merry-go-round, in what direction would the child move as the merry-go-round starts to rotate?

2006 Question 6(Higher Level)



(i) Define velocity.
(ii) Define angular velocity.
(iii) Derive the relationship between the velocity of a particle travelling in uniform circular motion and its angular velocity.
(iv) A student swings a ball in a circle of radius 70 cm in the vertical plane as shown. The angular velocity of the ball is 10 rad s^{-1}.
What is the velocity of the ball?
(v) How long does the ball take to complete one revolution?
(vi) Draw a diagram to show the forces acting on the ball when it is at position A.
(vii) The student releases the ball when is it at A, which is 130 cm above the ground, and the ball travels vertically upwards. Calculate the maximum height, above the ground, the ball will reach.
(viii) Calculate the time taken for the ball to hit the ground after its release from A.

Circular Motion and Gravity

2004 Question 12 (a) (Higher Level)

(i) State Newton's universal law of gravitation.
(ii) Centripetal force is required to keep the earth moving around the sun.
What provides this centripetal force?
(iii) In what direction does this centripetal force act?
(iv) Give an expression for centripetal force.
(v) The earth has a speed of 3.0×10^4 m s^{-1} as it orbits the sun.
The distance between the earth and the sun is 1.5×10^{11} m
Calculate the mass of the sun.
(gravitational constant $G = 6.7 \times 10^{-11}$ m^3 kg^{-1} s^{-2})

2013 Question 6 (Higher Level)

(i) State Newton's law of universal gravitation.
(ii) Explain what is meant by angular velocity.
(iii) Derive an equation for the angular velocity of an object in terms of its linear velocity when the object moves in a circle.

The International Space Station (ISS), shown in the photograph, functions as a research laboratory and a location for testing of equipment required for trips to the moon and to Mars.
The ISS orbits the earth at an altitude of 4.13×10^5 m every 92 minutes 50 seconds.

(iv) Calculate (*a*) the angular velocity, (*b*) the linear velocity, of the ISS.
(v) Name the type of acceleration that the ISS experiences as it travels in a circular orbit around the earth.
(vi) What force provides this acceleration?
(vii) Calculate the attractive force between the earth and the ISS.
(viii) Hence or otherwise, calculate the mass of the earth.

(ix) If the value of the acceleration due to gravity on the ISS is 8.63 m s^{-2}, why do occupants of the ISS experience apparent weightlessness?
(x) A geostationary communications satellite orbits the earth at a much higher altitude than the ISS.
What is the period of a geostationary communications satellite?
(mass of ISS = 4.5×10^5 kg; radius of the earth = 6.37×10^6 m)

2008 Question 6 (Higher Level)

(i) State Newton's law of universal gravitation.
(ii) The international space station (ISS) moves in a circular orbit around the equator at a height of 400 km.
What type of force is required to keep the ISS in orbit?
(iii) What is the direction of this force?
(iv) Calculate the acceleration due to gravity at a point 400 km above the surface of the earth.
(v) An astronaut in the ISS appears weightless. Explain why.
(vi) Derive the relationship between the period of the ISS, the radius of its orbit and the mass of the earth.
(vii) Calculate the period of an orbit of the ISS.
(viii) After an orbit, the ISS will be above a different point on the earth's surface. Explain why.
(ix) How many times does an astronaut on the ISS see the sun rise in a 24 hour period?
(gravitational constant = 6.6×10^{-11} N m^2 $kg^{-2;}$ mass of the earth = 6.0×10^{24} kg;
radius of the earth = 6.4×10^6 m)

2005 Question 6 (Higher Level)

(i) Define angular velocity.
(ii) Define centripetal force.
(iii) State Newton's Universal Law of Gravitation.
(iv) A satellite is in a circular orbit around the planet Saturn.
Derive the relationship between the period of the satellite, the mass of Saturn and the radius of the orbit.
(v) The period of the satellite is 380 hours. Calculate the radius of the satellite's orbit around Saturn.
(vi) The satellite transmits radio signals to earth. At a particular time the satellite is 1.2×10^{12} m from earth.
How long does it take the signal to travel to earth?
(vii) It is noticed that the frequency of the received radio signal changes as the satellite orbits Saturn.
Explain why.
Gravitational constant = 6.7×10^{-11} N m^2 kg^{-2}
mass of Saturn = 5.7×10^{26} kg
speed of light = 3.0×10^8 m s^{-1}

2015 Question 6 (Higher Level)

In the circular orbit of a satellite around the Earth, the required centripetal force is the gravitational force between the satellite and the Earth.
The force can be determined using Newton's law of universal gravitation.
(i) Explain what is meant by centripetal force.
(ii) State Newton's law of universal gravitation.
(iii) Derive the relationship between the period of a satellite, the radius of its orbit and the mass of the Earth.

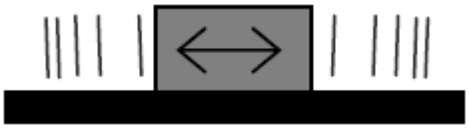
A Global Positioning Systems (GPS) receiver can calculate its position on Earth to within a few metres.
It picks up radio-wave signals from several of the 32 GPS satellites orbiting the Earth.
GPS satellites orbit the Earth in Medium Earth Orbit (MEO) with a period of 12 hours.

(iv) Calculate the height of a GPS satellite above the Earth's surface.
(v) Calculate the speed of a GPS satellite.
(vi) Calculate the minimum time it takes a GPS signal to travel from the satellite to a receiver on the surface of the Earth.
(vii) Explain why GPS satellites are not classed as geostationary satellites.
(viii) Radio-waves, such as those used by GPS satellites, have the lowest frequency of all electromagnetic radiation types.
What type of electromagnetic radiation has the next lowest frequency?
(mass of Earth = 5.97×10^{24} kg; radius of Earth = 6371 km)

Simple Harmonic Motion

2011 Question 12 (a) (Higher Level)

State Hooke's law.



A body of mass 250 g vibrates on a horizontal surface and its motion is described by the equation $a = -16\,s$, where s is the displacement of the body from its equilibrium position.

The amplitude of each vibration is 5 cm.

(a) Why does the body vibrate with simple harmonic motion?

(b) Calculate the frequency of vibration of the body?

(c) What is the magnitude of (i) the maximum force, (ii) the minimum force, which causes the body's motion?

2013 Question 11 (Higher Level)

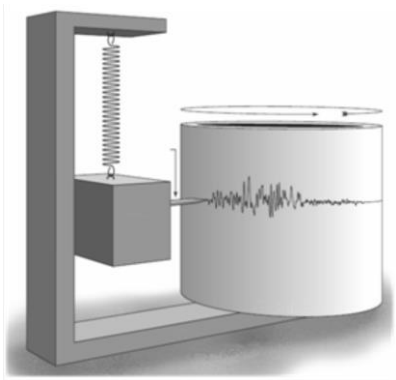
Read the following passage and answer the accompanying questions.

A seismometer consists of a sensor that detects ground motion, attached to a recording system.

A seismometer that is sensitive to up-down motions of the ground, as caused by an earthquake, can be understood by visualising a mass hanging on a spring as shown in the diagram.

The frame and the drum move up and down as the seismic wave passes by, but the mass remains stationary.

If a recording system is installed, such as a rotating drum attached to the frame and a pen attached to the mass, this relative motion between the suspended mass and the ground can be recorded to produce a seismogram, as shown in the diagram.



Modern seismometers do not use a pen and drum.

The relative motion between a magnet that is attached to the mass, and the frame, generates a potential difference that is recorded by a computer.

(Adapted from *www.iris.edu Education and Outreach Series No.7: How does a Seismometer Work?*)

(i) Seismic waves can be longitudinal or transverse.
What is the main difference between them?

(ii) An earthquake generates a seismic wave that takes 27 seconds to reach a recording station. If the wave travels at 5 km s^{-1} along the earth's surface, how far is the station from the centre of the earthquake?

(iii) Draw a diagram to show the forces acting on the suspended mass when the seismometer is at rest.

(iv) At rest, the tension in the spring is 49 N. What is the value, in kilograms, of the suspended mass?

(v) What type of motion does the frame have when it moves relative to the mass?

(vi) During an earthquake the ground was observed at the recording station to move up and down as the seismic wave generated by the earthquake passed. Give an equation for the acceleration of the ground in terms of the periodic time of the wave motion and the displacement of the ground.

(vii) If the period of the ground motion was recorded as 17 seconds and its amplitude was recorded as 0.8 cm, calculate the maximum ground acceleration at the recording station.

(viii) In some modern seismometers a magnet is attached to the mass and a coil of wire is attached to the frame. During an earthquake, there is relative motion between the magnet and the coil.
Explain why an emf is generated in the coil.

(ix) (acceleration due to gravity, $g = 9.8$ m s^{-2})

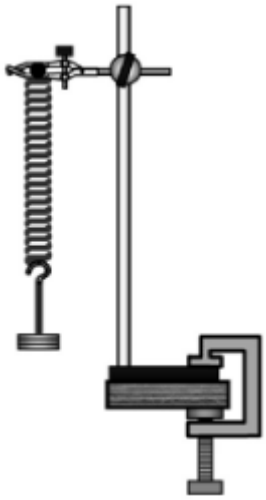
Tricky maths questions - points to note

- When using the F = k s expression for Hooke's Law, s represents the extension, i.e. the distance between the new length and the original (natural) length.
  However when using the expression for simple harmonic motion ($a = -\omega^2 s$) *s represents the distance between the new length and the equilibrium position.*

- Remember that the most common equation used here is the following:

$$\boldsymbol{\omega} = \sqrt{\frac{\boldsymbol{k}}{\boldsymbol{m}}}$$

2014 Question 12 (a) (Higher Level)



(i) State Hooke's law.
(ii) The elastic constant of a spring is 12 N m^{-1} and it has a length of 25 mm.
An object of mass 20 g is attached to the spring.
What is the new length of the spring?
(iii) The object is then pulled down until the spring's length is increased by a further 5 mm and is then released. The object oscillates with simple harmonic motion.
Sketch a velocity-time graph of the motion of the object.
(iv) Calculate the period of oscillation of the object.
(acceleration due to gravity, g = 9.8 m s^{-2})

2009 Question 12 (a) (Higher Level)

(i) State Hooke's law.
(ii) When a sphere of mass 500 g is attached to a spring of length 300 mm, the length of the spring increases to 330 mm.
Calculate the spring constant.
(iii) The sphere is then pulled down until the spring's length has increased to 350 mm and is then released.
Describe the motion of the sphere when it is released.
(iv) What is the maximum acceleration of the sphere?
(acceleration due to gravity = 9.8 m s^{-2})

2007 Question 6 (Higher Level)

(i) State Hooke's law.
(ii) A stretched spring obeys Hooke's law.
When a small sphere of mass 300 g is attached to a spring of length 200 mm, its length increases to 285 mm.
Calculate its spring constant.
(iii) The sphere is pulled down until the length of the spring is 310 mm.
The sphere is then released and oscillates about a fixed point.
Derive the relationship between the acceleration of the sphere and its displacement from the fixed point.
(iv) Why does the sphere oscillate with simple harmonic motion?
(v) Calculate the period of oscillation of the sphere
(vi) Calculate the maximum acceleration of the sphere
(vii) Calculate the length of the spring when the acceleration of the sphere is zero.
(acceleration due to gravity = 9.8 m s^{-2})

2002 Question 6 (Higher Level)

(i) State Newton's second law of motion.

(ii) The equation F = – ks, where k is a constant, is an expression for a law that governs the motion of a body.
Name this law and give a statement of it.

(iii) Give the name for this type of motion and describe the motion.

(iv) A mass at the end of a spring is an example of a system that obeys this law.
Give two other examples of systems that obey this law.

(v) The springs of a mountain bike are compressed vertically by 5 mm when a cyclist of mass 60 kg sits on it.
When the cyclist rides the bike over a bump on a track, the frame of the bike and the cyclist oscillate up and down.
Using the formula F = – ks, calculate the value of k, the constant for the springs of the bike.

(vi) The total mass of the frame of the bike and the cyclist is 80 kg.
Calculate (i) the period of oscillation of the cyclist, (ii) the number of oscillations of the cyclist per second. (acceleration due to gravity, $g = 9.8\ m\ s^{-2}$)