MECHANICS: CIRCULAR MOTION QUESTIONS

GRAVITATION (2011;3)

The diagram shows a satellite in orbit around the Earth (not to scale).

• Mass of the Earth = 5.97×10^{24} kg

• Polar radius of the Earth = 6.36×10^{6} m

(a) Label the diagram to identify the nature and direction of the force / forces on the satellite.

(b) Calculate the net force on a 1.08×10^{3} kg satellite when it is in a polar orbit 2.02×10^{7} m above the Earth's surface.

(c) Show that the only stable orbit for the satellite orbiting at an altitude of 2.02×10^{7} m has a period of approximately 12 hours.

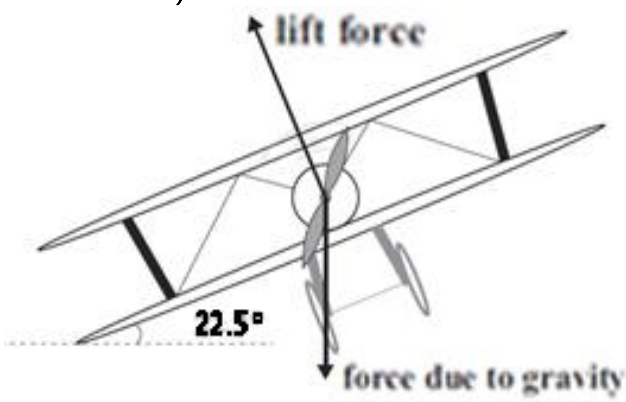
(d) For any object orbiting around a primary body, $R^3 \propto T^2$, where R is the radius of the orbit and T is the time period for the orbit. Show that this is true, and in doing so state the conditions required for a stable orbit and show that the conditions do not depend on the mass of the orbiting object.

(e) Discuss the particular requirements for an orbit that will keep a satellite vertically above a certain point on the Earth's surface.

QUESTION ONE (2009;1)

Sam enjoys flying vintage aeroplanes. One of the planes Sam flies has a mass, when operating, of 635 kg.

In order to turn the plane in a horizontal circle at constant speed, Sam tilts, or banks, the plane at an angle of 22.5°. The free-body forces on the plane are shown in the diagram below.
(Acceleration due to gravity = 9.81 ms^{-2})



(a) Show that the size of the vertical component of the lift force is 6230 N.

(b) Calculate the size and direction of the resultant force on the plane during this turn.

In another constant speed horizontal turn, the plane has a centripetal acceleration of 2.50 ms^{-2}.

(c) Calculate the angle of banking of the plane in this turn.

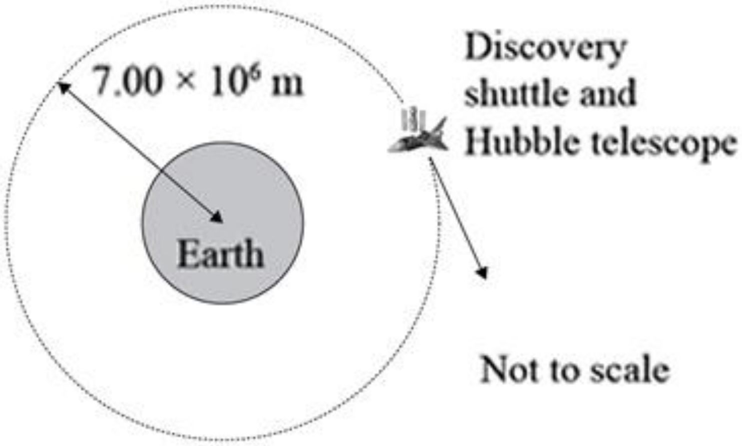
(d) For a plane to turn in a horizontal circle at a steady speed, it is necessary to tilt the plane. By considering all the forces that act on the plane, explain why this is the case.

SPACE – THE FINAL FRONTIER (2006;2)

Universal Gravitational Constant = 6.67×10^{-11} Nm^2 kg^{-2}.
Mass of Earth = 5.98×10^{24} kg

Part One

The space shuttle Discovery went into a circular orbit of radius 7.00×10^6 m to release the Hubble space telescope, which was attached to the shuttle by a cable. The diagram below shows the shuttle / telescope system orbiting Earth before the shuttle and telescope separated.



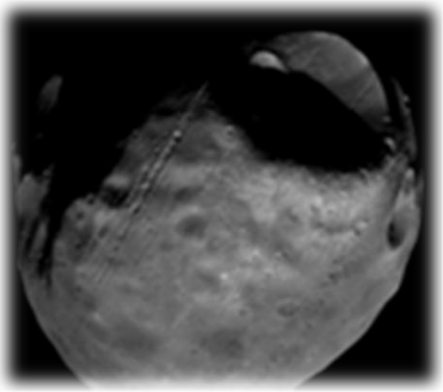
(a) Name the force that is keeping the shuttle / telescope system in this circular orbit, and state the direction in which this force is acting.

(b) Calculate the value of the acceleration due to Earth's gravity (strength of Earth's gravitational field) at this height above Earth's surface. Write your answer to an appropriate number of significant figures.

(c) Weight is felt as a reaction force. Explain why an astronaut in the shuttle feels 'weightless' while in orbit about Earth.

Part Two

Phobos is one of the moons of Mars. It orbits around Mars at a mean radius 9.38×10^6 m with a period of 2.76×10^4 s.



(d) From this information, calculate the mass of Mars.

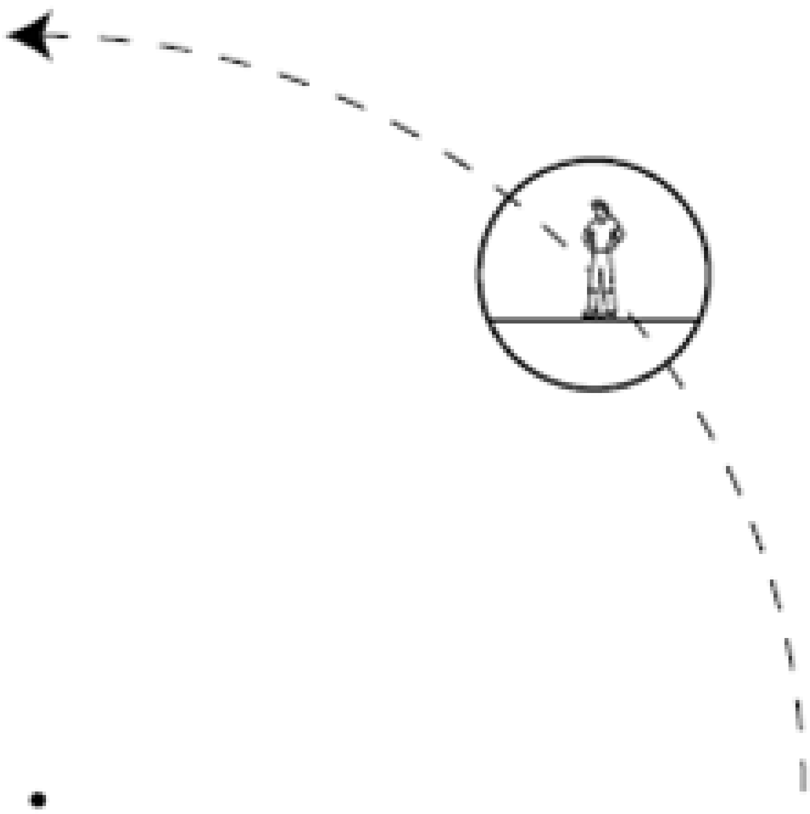
LINEAR AND ROTATIONAL MOTION (2005;1)

The London Eye is a giant rotating wheel that has 32 capsules attached at evenly spaced intervals to its outer rim. Passengers riding in the capsules get spectacular views over London, especially at the top.

Capsule

The capsules each have mass 1.0×10^4 kg and are at a distance of 68 m from the centre of the wheel. They travel at a constant speed of 0.26 ms^{-1}.

(a) Calculate the size of the centripetal force that is maintaining the vertical circular motion of a capsule about the centre of the wheel.



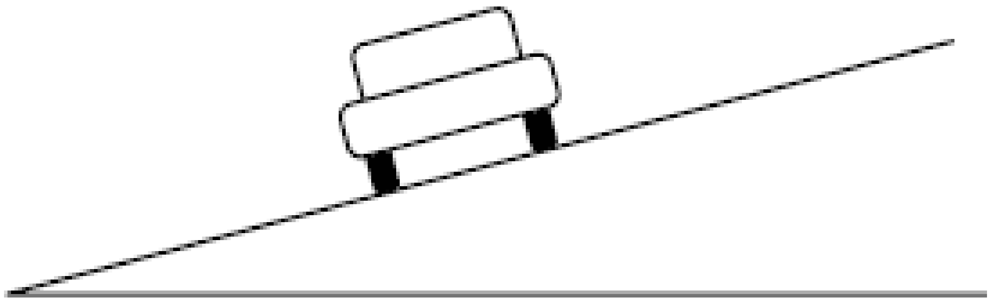
(b) On the diagram above, draw a labelled free-body force diagram to show how the forces on the passenger combine to give the centripetal force causing her to move in a circle.

DRIVING ON BANKED CORNERS (2004;3)

Use the gravitational field strength = 9.80 N kg^{-1} (or acceleration due to gravity = 9.80 ms^{-2}).

Moana is driving home from work in her car. At one point she drives around a bend in the road that has a horizontal radius of 90.0 m and banking at an angle of 6.50°. Bends in roads are banked so that cars can travel around them at the same speed as on straight parts without sliding. The mass of Moana and the car is 995 kg. Assume the friction force acting up or down the slope is zero.

(a) On the diagram below, draw a free body force diagram to show the reaction force, F, and the gravitational force, F, acting on Moana's car. Label both vectors.



(b) On the diagram, draw and label an arrow to show the direction of the unbalanced force acting on the car.
(c) Calculate the value of the vertical component of the reaction force.
(d) In terms of the forces acting on the car, explain why the car will travel around the bend.
(e) Calculate the speed of the car as it drives around the bend.
(f) Explain what would happen to this speed if the banking angle of the road had been greater but friction remained zero.