Motion in a Circle

Question paper 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Motion in a circle
Sub Topic	
Paper Type	Theory
Booklet	Question paper 1

Time Allowed: **60 minutes**

Score: **/50**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 A large bowl is made from part of a hollow sphere.

A small spherical ball is placed inside the bowl and is given a horizontal speed. The ball follows a horizontal circular path of constant radius, as shown in Fig. 2.1.

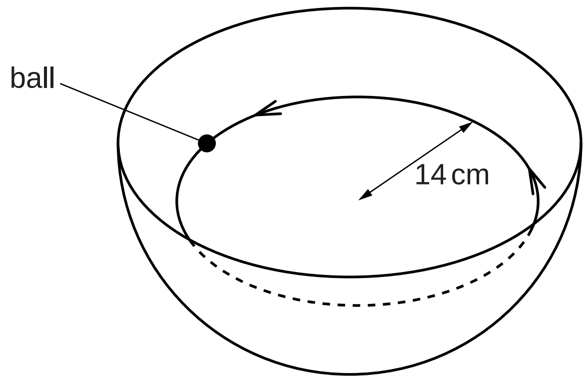

Fig. 2.1

The forces acting on the ball are its weight *W* and the normal reaction force *R* of the bowl on the ball, as shown in Fig. 2.2.

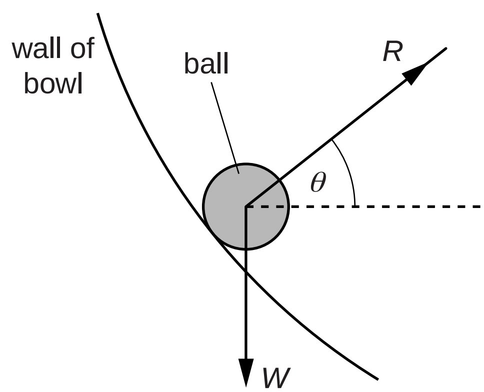

Fig. 2.2

The normal reaction force *R* is at an angle θ to the horizontal.

(a) **(i)** By resolving the reaction force *R* into two perpendicular components, show that the resultant force *F* acting on the ball is given by the expression

$$W = F \tan\theta.$$

[2]

(ii) State the significance of the force F for the motion of the ball in the bowl.

....

.... [1]

(b) The ball moves in a circular path of radius 14 cm. For this radius, the angle θ is 28°.

Calculate the speed of the ball.

speed = ... $m\,s^{-1}$ [3]

2 **(a)** Define the *radian*.

....

....

.... [2]

(b) A telescope gives a clear view of a distant object when the angular displacement between the edges of the object is at least 9.7×10^{-6} rad.

(i) The Moon is approximately 3.8×10^{5} km from Earth.
Estimate the minimum diameter of a circular crater on the Moon's surface that can be seen using the telescope.

diameter = ... km [2]

(ii) Suggest why craters of the same diameter as that calculated in **(i)** but on the surface of Mars are not visible using this telescope.

....

....

.... [2]

3 **(a)** A moon is in a circular orbit of radius r about a planet. The angular speed of the moon in its orbit is ω. The planet and its moon may be considered to be point masses that are isolated in space.

Show that r and ω are related by the expression

$$r^3\omega^2 = \text{constant}.$$

Explain your working.

[3]

(b) Phobos and Deimos are moons that are in circular orbits about the planet Mars. Data for Phobos and Deimos are shown in Fig. 1.1.

moon	radius of orbit / m	period of rotation about Mars / hours
Phobos	9.39×10^6	7.65
Deimos	1.99×10^7	

Fig. 1.1

(i) Use data from Fig. 1.1 to determine

1. the mass of Mars,

mass = ... kg [3]

2. the period of Deimos in its orbit about Mars.

period = ... hours [3]

(ii) The period of rotation of Mars about its axis is 24.6 hours.
Deimos is in an equatorial orbit, orbiting in the same direction as the spin of Mars about its axis.

Use your answer in **(i)** to comment on the orbit of Deimos.

....

....[1]

4 A planet of mass m is in a circular orbit of radius r about the Sun of mass M, as illustrated in Fig. 1.1.

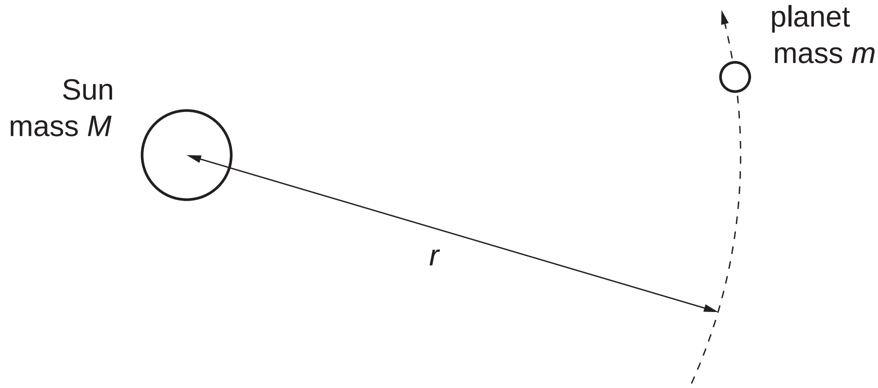

Fig. 1.1

The magnitude of the angular velocity and the period of revolution of the planet about the Sun are ω and T respectively.

(a) State

(i) what is meant by *angular velocity*,

....

....

.... [2]

(ii) the relation between ω and T.

.... [1]

(b) Show that, for a planet in a circular orbit of radius r, the period T of the orbit is given by the expression

$$T^2 = cr^3$$

where c is a constant. Explain your working.

[4]

(c) Data for the planets Venus and Neptune are given in Fig. 1.2.

planet	r / 10^8 km	T / years
Venus	1.08	0.615
Neptune	45.0	

Fig. 1.2

Assume that the orbits of both planets are circular.

(i) Use the expression in **(b)** to calculate the value of T for Neptune.

T = ... years [2]

(ii) Determine the linear speed of Venus in its orbit.

speed = ... km s^{-1} [2]

5 **(a)** Define the *radian*.

....

....

.... [2]

(b) A stone of weight 3.0 N is fixed, using glue, to one end P of a rigid rod CP, as shown in Fig. 1.1.

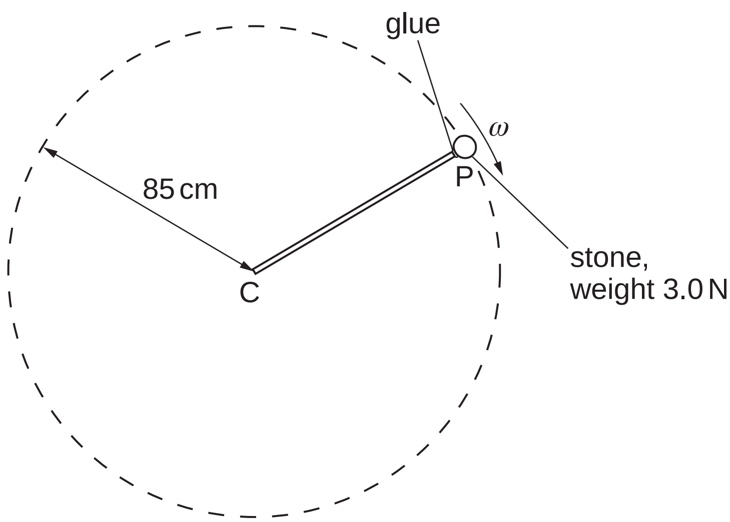

Fig. 1.1

The rod is rotated about end C so that the stone moves in a vertical circle of radius 85 cm.
The angular speed ω of the rod and stone is gradually increased from zero until the glue snaps. The glue fixing the stone snaps when the tension in it is 18 N.

For the position of the stone at which the glue snaps,

(i) on the dotted circle of Fig. 1.1, mark with the letter S the position of the stone, [1]

(ii) calculate the angular speed ω of the stone.

angular speed = ... rad s^{-1} [4]

6 A spherical planet has mass *M* and radius *R*.
The planet may be assumed to be isolated in space and to have its mass concentrated at its centre.
The planet spins on its axis with angular speed ω, as illustrated in Fig. 1.1.

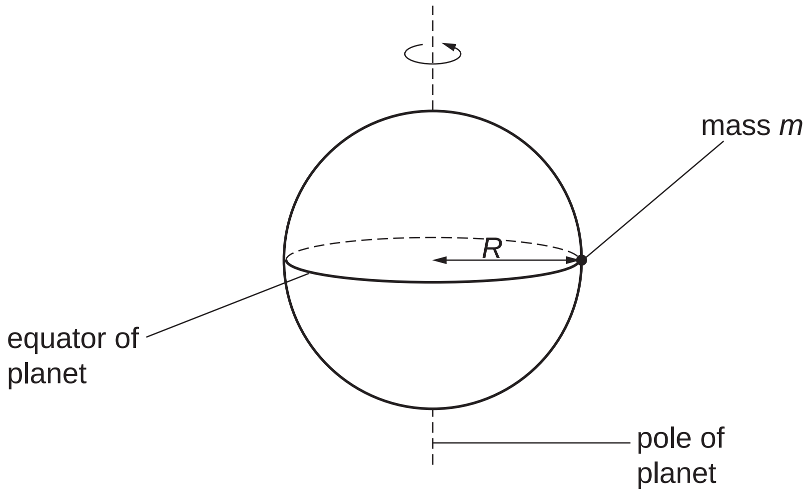

Fig. 1.1

A small object of mass *m* rests on the equator of the planet. The surface of the planet exerts a normal reaction force on the mass.

(a) State formulae, in terms of *M*, *m*, *R* and ω, for

(i) the gravitational force between the planet and the object,

.... [1]

(ii) the centripetal force required for circular motion of the small mass,

.... [1]

(iii) the normal reaction exerted by the planet on the mass.

.... [1]

(b) (i) Explain why the normal reaction on the mass will have different values at the equator and at the poles.

....

....

.... [2]

(ii) The radius of the planet is 6.4×10^6 m. It completes one revolution in 8.6×10^4 s. Calculate the magnitude of the centripetal acceleration at

1. the equator,

acceleration = ...$m\,s^{-2}$ [2]

2. one of the poles.

acceleration = ...$m\,s^{-2}$ [1]

(c) Suggest two factors that could, in the case of a real planet, cause variations in the acceleration of free fall at its surface.

1. ....

....

2. ....

....
[2]