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Physics (Assignment WK-5)

Question 1:

When a object ralls without slipping, its total mechanical energy is conserved. This includes both transitional and rotational kinetic energy.

1. Initial Energy at Hieght

- The sphere starts from rest, so its initial kinetic energy is zero.
- Its potential energy is mgh, where m is the mass, g is acceleration due to gravity h is hieght.

2. Energy at Bottom

- At the bottom, the potential energy is zero.
- The kinetic energy is combination of translational kinetic energy ($\frac{1}{2}mv^2$) and where I is the moment of Inertia and ω is angular velocity.

For a solid sphere, the moment of

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Inertia I is $\frac{2}{5}mr^2$ and the relationship between the linear velocity, the moment of Inertia ω is $\omega = \frac{v}{r}$

The total energy at the bottom is

$$\frac{1}{2}mv^2 + \left(\frac{1}{2}mr^2\right)\left(\frac{v}{r}\right)^2$$

Simplifying the rotational kinetic energy term: $\frac{1}{2} \cdot \frac{2}{5}mr^2 \frac{v^2}{r^2} = \frac{1}{5}mv^2$

So, the total kinetic energy at the bottom is:

$$\frac{1}{2}mv^2 + \frac{1}{5}mv^2 \; \frac{7}{10}mv^2.$$

Question 2.

For an object to be in a stable low earth orbit, this velocity can be calculated using the formula for orbital velocity:

$$\text{velocity} = \sqrt{\frac{GM}{r}}$$

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Where:

- G is the gravitational constant. 6.674×10^{-11} Nm^2/kg^2
- M is the mass of earth approximately 5.972×10^{24} kg.
- r is the distance from the centre of the earth to the object, which for a low earth orbit is roughly equal to the Earth radius plus the altitude of the orbital / ranging from about 200km to 2000km above the Earth's surface. However, to simplify we often use the Earth radius (6.371×10^6 m) for basic calculation.

. using the approximate values, we can calculate.

$$\text{vertical} \approx \sqrt{\frac{(6.674 \times 10^{-11})(5.972 \times 10^{24})}{6.371 \times 10^6}}$$

When you compelete this, you find that vertical $= 7000$ m/s.

Since 79000 m/s is essentially 7.9 km/s.

Question.no.3

We can use the concept of apparent weight.

1. Understanding Weight in Physics

- The actual weight W of a person is the gravitational force acting on them, which is mg, where m is the mass of a person and g is the acceleration due to gravity.

2. Apparent weight in an Elevator

- When the elevator is at rest or moving at a constant velocity, the apparent weight is equal to actual weight
- When the elevator accelerates, the apparent weight is the normal

Force N exerted by the floor. This changes due to the accleration of the elevator.

3. Elevator Accelerating Upward

- If the elevator accelerates upward with acceleration a, the apparent weight can be expressed using Newton's second law:

$$N = m(g+a)$$

- In this case, a is equal to g. Therefore,

$$N = m(g+g) = 2mg$$

- Thus, the apparent weight N becomes 2W, since $W = mg$ the person weight

Thus, when in the elevator will be 2W when the elevator accelerating upward with an acceleration equal to g.

Question.no.4

Given:

- Speed of the satellite, $v = 1.01$ Km/s
- Radius of the orbit, $r = 390,400$ km

To find the time T it takes for the satellite to complete one revolution, we use the formula for the circumference of the orbit and the relationship between distance, speed and time.

$$C = 2\pi r$$

$T = \frac{C}{v} = \frac{2\pi r}{v}$

First let's calculate the circumference:

$C = 2\pi \times 390,400km \approx 2,4,52,629km$

Now, the time to complete one revolution:

$T = \frac{2,452,629km}{1.01km/s}$

$T \approx 2,428,347s$

To convert seconds into days:

$T \approx \frac{2,428,3477s}{81} \approx 28.11 days.$

Therefore, the satellite will complete one revolution approximately every 28.11 days.

Question.no. 5

The formula for the orbital radius r of a geostationary statellite is given by:

$$r = \left(\frac{GMT^2}{4\pi^2}\right)^{1/3}$$

Where,

- G is the gravitational constant (6.674 $\times 10^{-11} m^3/kgs^2$).
- M is the mass of earth 5.972×10^{24} kg
- T is the orbital period (one sidereal day in seconds: 86164s).

Given these values, we compute the orbital radius r:

$$r = \left(\frac{(6.674 \times 10^{-11}) \times (5.972 \times 10^{24}) \times (86164)}{4\pi^2} \right)$$

Upon calculating this, we find:

$r = 42,164$ km.

This is the distance from the center of the earth.

Question.no.6

Given:-

Diameter of beam = length of arc = $S = 2.50$ m

Distance of moon from the earth = $r = 3.8 \times 10^8$ m

Find:-

Divergence angle = θ = ?

Calculation:-

As, $S = r\theta$

$$\theta = \frac{S}{r}$$

Putting values, we get

$$\theta = \frac{2.50}{3.8 \times 10^8}$$

$$\theta = 0.6 \times 10^{-9} \text{ rad.}$$

Question.no.7

Given:-

Distance between Earth and the Moon $= r_o = 3.85\times10^8 m$

Radius of the moon $= r_s = 1.74\times10^6 m$

Find:-

Ratio of spin and orbital angular $= \frac{L_s}{L_o} = ?$

Calculation:-

The spin angular momentum of the Moon about its own axis is

$$L_s = I_s\omega$$

$$L_s = \frac{2}{5} m r_s^2 \omega \;..... (1)$$

The orbital angular momentum is given by

$$L_o = I_o\omega$$

$$L_o = m r_o^2 \omega \;— (2)$$

Dividing equation (1) by equation (2) we get

$$\frac{L_s}{L_o} = \frac{\frac{2}{5} m r_s^2 \omega}{m r_o^2 \omega}$$

$$\frac{L_s}{L_o} = \frac{2}{5}\frac{r_s^2}{r_o^2}$$

putting values, we get

$$\frac{L_s}{L_o} = \frac{2}{5}\frac{(1.74\times10^6)^2}{(3.85\times10^8)^2}$$

$$\frac{L_s}{L_o} = 8.2\times10^{-6}$$

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