BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI (RAJ)

FIRST SEMESTER 2016-2017

MID SEMESTER TEST (Closed Book)

Course No.: PHY F111 **Mechanics, Oscillations & Waves** Max. Marks**: 90**

Date: 03.10.2016 Max Time: 90 minutes

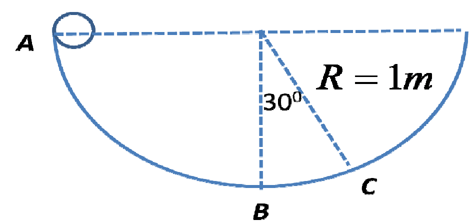
Note: 1. Write correct tutorial section number and instructor's name on the answer sheet.

2. Do all the parts of a question together.

3. Take g = 9.8 m/sec^2

Q1. A solid uniform cylinder of radius r ($I_{CM} = \frac{2}{5}Mr^2$) rolls without sliding along the inside surface of a horizontal, fixed cylinder of radius R. It performs small oscillations at the bottom of the cylinder. Find the period of this small oscillations. **[10]**

Q2. A tiny spherical shell of radius r ($I_{CM} = \frac{2}{5}Mr^2$) rolls without slipping on the inner surface of a large fixed hemispherical container of radius R, as shown in the figure. If the shell is released at point A, what is its linear speed (a) at point B, and (b) at point C. **[10]**



Q3. A roller of radius R ($I_{CM} = \frac{1}{3}MR^2$) is released from rest at the top of a fixed incline of height h. It rolls without slipping down the incline, and then a long way along a rough horizontal road until it collides elastically with a smooth rigid vertical wall. When the roller again begins to roll without slipping on the horizontal road, what is the speed of its center of mass? (Assume that the length of the road is long enough so that the rolling occurs before the roller reaches inclined plane after colliding with the rigid wall) **[10]**

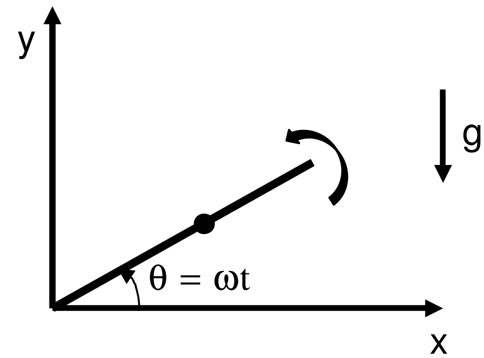
Q4. A heavy circular, horizontal platform is rotating with constant angular velocity ω about its central vertical axis. A car of mass M is driven at a constant velocity v_0 along a marked radial line on the platform, starting from the centre at t = 0. You may choose the fixed radial line to be the x-axis, and the vertical axis to be the z-axis, so that $\vec{v} = v_0\hat{x}$ and $\vec{\omega} = \omega\hat{z}$. (**This problem is to be solved in the rotating frame of the platform.)**

a) Write down the net fictitious force acting on the car as a function of time.

b) Write down the equation of motion of the car in the rotating frame of the platform, and using this, find the frictional force on the car as a function of time. The coefficient of friction between the car and the platform is μ.

c) Find the time t at which the car will begin to skid on the platform? **[7+7+4]**

Q5. A frictionless rod is pivoted at one end and rotates in a vertical plane with constant angular velocity ω, starting from the horizontal position at $t = 0$, as shown in the figure. A bead of mass m is free to slide along the rod. Acceleration due to gravity, as shown, is g.

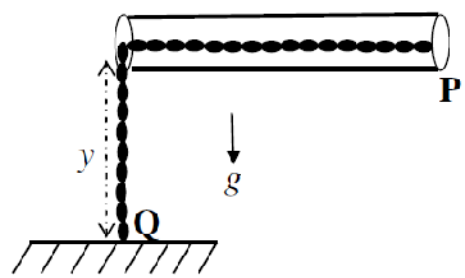


a) Draw the force diagram of the bead and write down its equations of motion in the polar coordinates r & θ.

b) By direct substitution into the equation of motion for r, show that $r(t) = \frac{g}{2\omega^2}\left(Ae^{-\omega t} + Be^{\omega t} + \sin\omega t\right)$ is a solution for arbitrary constants A & B.

c) Find the condition on the initial position $r(0) = r_0$ and initial velocity $\dot{r}(0) = v_0$, that will make r(t) an exponentially decaying function of time, so that the term $e^{\omega t}$ is absent in the solution. **[6+5+4]**

Q6. A uniform rope (mass λ per unit length) PQ of length l is hanging out of a pipe such that a portion y of the rope hangs freely and touches the surface of the table with its end Q as shown in figure. At a certain point of time the end P of the rope is set free. With what velocity will this end of the rope slip out of the pipe? **[12]**



Q7. Two identical blocks, each of mass m are linked together by a weightless spring of spring constant k as shown in figure. At equilibrium, the length of the spring is l_0. Initially, the upper block is compressed by Δl as shown in figure and the system is released.

Find

(i) for what minimum value of Δl, the lower block will just bounce up after the system is released?

(ii) to what height the center of mass of this system will rise, if the initial compression of the spring is $\Delta l = 5mg/k$. **[8+7]**