1. As shown in the following figure, Oxy is a fixed frame in the horizontal plane and a large ring with diameter D is fixed to a rod $\overline{OA}$ of which the extension passes the center of the ring. The length of $\overline{OA}$ is a and the angle between $\overline{OA}$ and the x- axis is θ. Inside the large ring, there is a small ring with diameter d which is rolling without slipping. Consider a point P on the small ring. Assume that the angle between $\overline{oP}$ and $\overline{oh}$ which is parallel to the x- axis is ϕ. Also, assume that the angular velocities of $\overline{OA}$ and $\overline{oP}$ are $\Omega = \dot{\theta}$ and $\omega = \dot{\phi}$, respectively. For the position shown, determine the acceleration of the point P. (20%)

2. As shown in the following figure, Oxh is a fixed frame in the vertical plane. A cannon with mass m is flying with velocity V and flight path angle γ (the angle between the velocity and the horizon). Assume that the drag (which is parallel to and in opposition of $\mathbf{V}$) is $D = KV^2$ where K is constant. Let the position and velocity of the cannon (which can be considered as a point mass) is $\mathbf{r}$ and $\mathbf{V}$, respectively. Determine the equations of motion (i.e., write $\dot{\mathbf{r}} = \mathbf{V}$ and $\dot{\mathbf{V}} = (\sum \mathbf{Forces})/m$ in component forms) and solve them as far as you can. (20%)
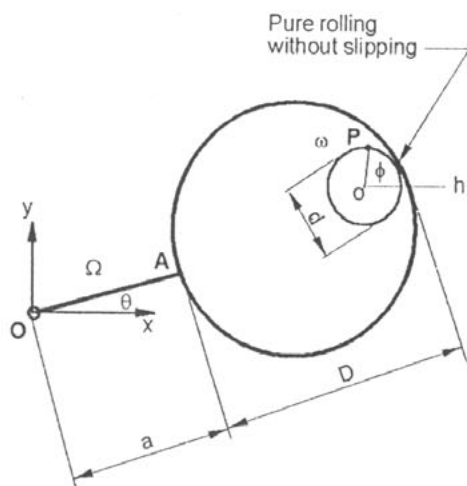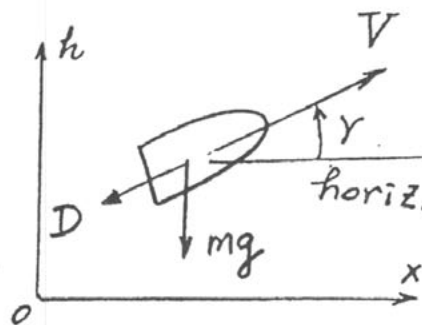

Figure 1

Figure 2

1

3. A 10-N collar slides down from A with zero initial speed along the smooth rod. During the motion, a force $\mathbf{F} = (50xi + 30yj + 10zk)$ N is applied to the collar, where x, y, and z are in meters. Find the collar's speed when it reaches B in figure 3. (20%)

4. Consider a car driving down a slope represented by the rolling disk down a slope model as shown in figure 4. Explain how can a moving car be stopped on the slope by stepping on the car break? (20%)

5. As shown in figure 5, a uniform slender bar AB of mass M and length L is supported by a shaft at its center of mass. The shaft rotates with a constant rate ω. End B is connected horizontally to the shaft by a cord, which keeps a constant angle β between the bar and the shaft. Determine the reaction force on the cord. (20%)
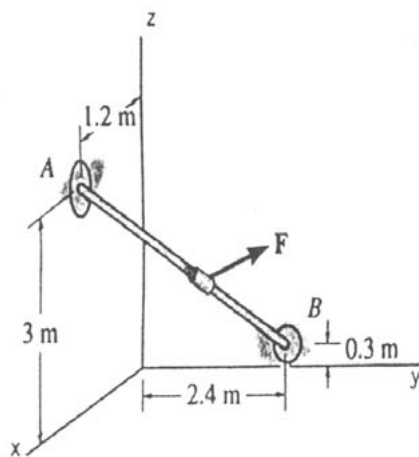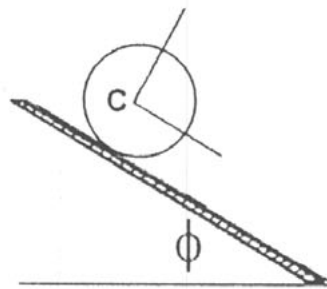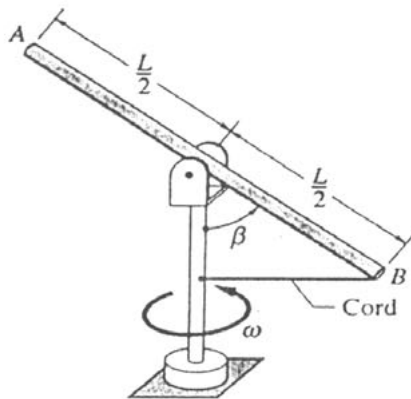
Figure 3

Figure 4

Figure 5