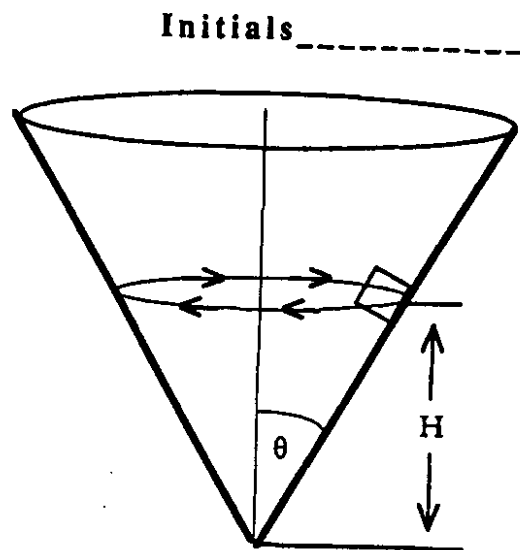


Problem 7 (35 points)

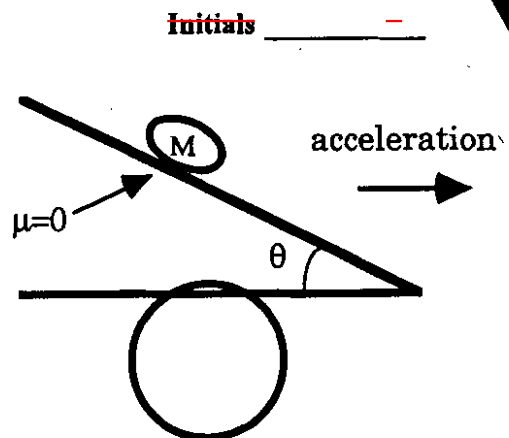
A small car is driving in a horizontal circle on the inside surface of a cone as shown. The car has mass, M , and is moving with a constant speed of V . Assume that there is no friction acting on the car. The horizontal circle is located at a height, H , above the point of the cone as shown on the drawing. The angle between the center of the cone and the side (the half-angle) is θ as shown.



- Draw a free-body diagram showing all the forces acting on the car. Also, draw an arrow indicating the direction of any acceleration.
- In terms of the given quantities and the acceleration of gravity, g , find the value of the normal force acting on the car.
- In terms of the given quantities and the acceleration of gravity, g , find the value of the constant speed, V , for which the car can continue to move in a horizontal circle at a height, H , with no friction acting along the incline. (Hint: If you do the physics, trigonometry, and algebra correctly, the trig functions all cancel and the answer is independent of θ)

Problem 8 (20 points)

A bead of mass M sits on the sloped hood of a car. The hood is at an angle θ from the horizontal and the car is accelerating to the right as shown. Assume that air resistance on the bead and friction between the bead and the hood of the car are both so small that they can be ignored. As the car accelerates, the bead moves along with the car but it does not move up or down the slope of the hood.



- Draw a free-body diagram for the bead showing all of the forces acting on it.
- Pick a choice of X and Y axes, show them on your diagram, and write $F=ma$ equations for the two directions.
- Find the magnitudes of the normal force of the hood on the bead and the acceleration of the car. Express your answers in terms of M , g , and θ , noting that the results may depend on only one or two of these values.

b) $\sum F_x = B \sin(\theta) - f = 0, f = B \sin(\theta)$
 $\sum F_y = -B \cos(\theta) + N = 0, N = B \cos(\theta)$

c) B will not move if $f < \mu N, B \sin(\theta) < \mu B \cos(\theta)$
 B drops out. Block will move if $\sin(\theta) > \mu \cos(\theta)$, or $\tan(\theta) > \mu$

Problem 5

a) $y = H + vt - \frac{1}{2}gt^2, y = H$ at $vt - \frac{1}{2}gt^2 = 0, t = \frac{2v}{g}$.

b) $N = B$ by Newton's 3rd law.

c) $N = 0$ No contact.

d) $E_I = 0, E_F = m_y H + \frac{1}{2}mv^2, W = BH - E_F - E_I \Rightarrow B = m_y + \frac{mv^2}{2H}$

Problem 6

a) $F_x = F \cos(\theta) = \frac{2mg}{\tan(\theta)}, a_x = \frac{2g}{\tan(\theta)}$

$x = 100t + \frac{1}{2}a_x t^2 = 100(12) + \frac{1}{2} \frac{2g}{\tan(\theta)} (12)^2 = 1200 + \frac{1440}{\tan(\theta)}$

$\sum F_y = F \sin(\theta) - mg = 2mg - mg = mg, a_y = +g$

$y = 0 + \frac{1}{2}g \cdot (12)^2 = 720.$

b) This problem uses a calculator, your exam will not require a calculator.

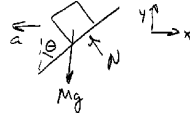
$v_x = 100 + \frac{2g}{\tan(\theta)} (12) = 239 \text{ m/s}$.

$v_y = g \cdot (12) = 120 \text{ m/s}$

$v = \sqrt{v_x^2 + v_y^2} = 267 \text{ m/s}$, at 26.7° above horizontal.

Problem 7

a)



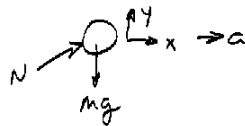
b) $\sum F_y = 0 - mg + N \sin(\theta) = 0, N = \frac{mg}{\sin(\theta)}$

c) $\sum F_x = -N \cos(\theta) = -m \frac{v^2}{R}, R = H \tan(\theta)$

Use answer to (b): $\frac{mg}{\sin(\theta)} \cos(\theta) = \frac{mv^2}{H \tan(\theta)}, v^2 = \sqrt{Hg}$.

Problem 8

a)



b) $\sum F_x = N \sin(\theta) = ma, \sum F_y = N \cos(\theta) - mg = 0.$

c) $N = \frac{mg}{\cos(\theta)}, a = \frac{N \sin(\theta)}{m} = g \tan(\theta).$