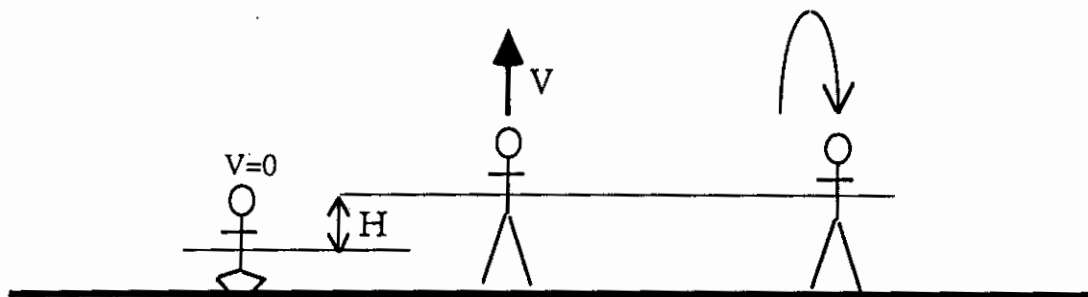


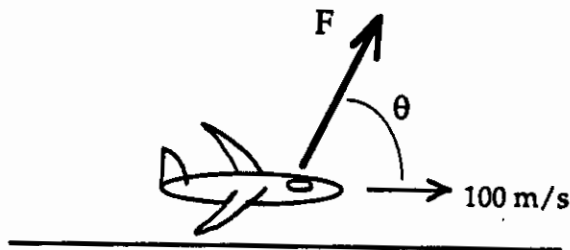
Problem 5 (25 points) The physics of Michael Jordan



A basketball player wants to jump straight up. He starts the motion crouched down at rest (left picture) and first pushes against the ground, raising his center of mass by a distance H . Assume that during this motion, the force his legs exert is a constant equal to B . At the point where he has moved up a distance H , his feet leave the ground and he has an upward velocity of V (middle picture). Answer the following questions in terms of the distance, H , the player's mass, M , the velocity V , the force magnitude B , and the acceleration due to gravity, g .

- How long does it take for the player to return to the ground (i.e. when is his center of mass again at a height of H , right picture, assuming that he started at that same height)? Assume that the motion is straight up and down, no horizontal movement at all.
- What was the normal force on his feet due to the floor right before he left the ground?
- What was the normal force on his feet due to the floor right after he left the ground?
- Find the magnitude of B in terms of the other variables.

6



A jet is moving horizontally down a runway. At the instant that it leaves the runway, it is moving at a speed of $v_0 = 100 \text{ m/s}$. The combination of the thrust of the jet engine and the lift of the wings produce a force on the plane that makes an angle θ with the horizontal as shown. Use $g = 10 \text{ m/s}^2$ to solve this problem. Using M for the mass of the plane, assume that the magnitude of the force is given by:

$$F = \frac{2Mg}{\sin \theta}$$

- (15 pts) Assume that the magnitude and direction of this force doesn't change after the plane leaves the runway. Find the horizontal and vertical distance that the plane has moved in a time of 12 seconds after taking off.
- (10 pts) Find the magnitude and direction of the velocity of the jet at a time of 12 seconds after takeoff. For this part of the problem only, use $\theta = 60^\circ$.

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

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.

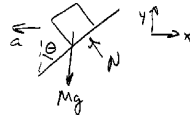
$v_x = 100 + \frac{2g}{\tan(\theta)} (12) = 239 \text{ m/s}$.

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

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

Problem 7

a)



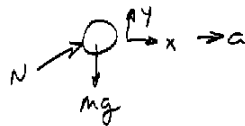
b) $\sum F_y = 0 - mg + N \sin(\theta) = 0, N = \frac{mg}{\sin(\theta)}$

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