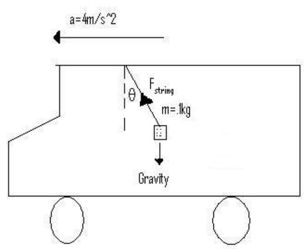
1 Selected Chapter 4 Problems

The most important equation of this chapter is $\vec{F} = m \times \vec{A}$, which I will refer to as equation 1.

1. Back in the 80's it was common to hang fuzzy dice from the rear view mirror of a car. Assuming you are driving such a car, and from a stoplight, you go from rest to 32.0m/s in 8s. The mass of fuzzy dice is m=.10kg. Determine the angle at which the fuzzy dice will hang during this acceleration.
Ans) The first step in any problem involving forces is to draw the free body diagram.

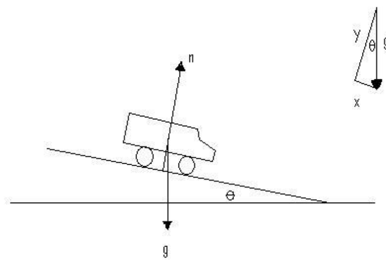


Note that I have already solved for the acceleration of the car by using $a = \frac{v}{t} = \frac{32m/s}{8s} = 4\frac{m}{s^2}$. Thinking about why the dice hang at an angle during acceleration I realize it is because they have inertia and wish to remain at rest, instead of accelerating forwards. There is a forward force on the car and thus, where the string is attached to the car. Therefore the string exerts an equal and opposite force on the car and this is the force that the dice feels, which I have labeled F_string. Now we have a problem in two dimensions. We use equation 1 in both directions to solve for the forces in each direction. Once done, we will have two legs for a right triangle and can use trigonometry to find the angle.

$$F_x = .1kg \times 4m/s^2 = .4N$$
$$F_y = .1kg \times 9.8m/s^2 = .98N$$
$$tan\Theta = \frac{x - component}{y - component} = \frac{.98N}{.4N}$$
$$\Theta = 22^o$$

2. A car of mass m is on an icy driveway at an angle of 20^o. a) Determine the acceleration of the car, assuming the incline is frictionless. b) If the length of the driveway is 25.0m, how long does it take for the car to reach the bottom

of the driveway?
Ans) Our free body diagram is our starting point.



The thing in the upper left corner is how to break gravity down into x and y components. We see that the only thing causing the car to accelerate down the incline is the force of gravity in the x-direction. So, since x-is the opposite side to the angle, we get that

$$F_x = m \times a_x = F_g \times sin\Theta = m \times 9.8m/s^2 \times sin(20)$$
$$a_x = 9.8m/s^2 \times sin(20) = 3.35m/s^2$$

To find the time we simply revert back to chapter 2 ideas. If the x-axis is pointing down the slope, the equation of motion is

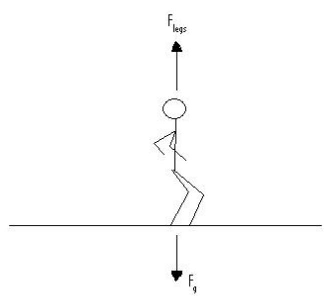
$$x = x_0 + v_0 \times t + 1/2 \times a \times t^2$$
$$25.0m = 0 + 0 \times t + 1/2 \times 3.35m/s^2 \times t^2$$
$$t = 3.86s$$

3. You and your friends are playing tug-of-war. If your friend pulls with a strength of 50N horizontally, what force must you pull with if you pull at an angle of 12^o above the horizontal to keep from moving left or right?
Ans) Again, start with the free body diagram.

Now, if you don't want to move it means that the acceleration is going to be zero. Therefore, $\Sigma F = 0$. The forces that we are concerned with are only those in the x-direction so we use cosine to find the force you apply in the x-direction. Writing down our forces from the picture we drew gives

$$\Sigma F = 0$$
$$F_{friend} + F = 0$$
$$-50N + F \times cos(12^o) = 0$$
$$F = 51N$$

4. In an internation basketball competition Vince Carter, who has a mass of 95kg, once jumped OVER a 7'2" French center to dunk the ball. Assuming his vertical leap reaches about 50 inches, and that he takes .05s to push off the ground, what is the force that his legs provide to jump this high? Ans) We begin by drawing a free body diagram of him as he jumps.



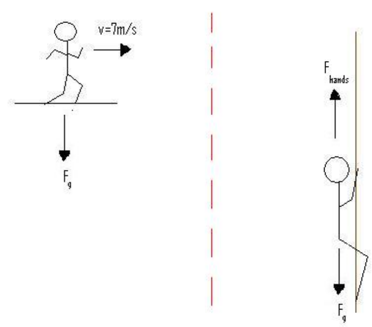
To find the F_{legs} we need the acceleration, and to find the acceleration we need to find the initial velocity he pushes off the floor with, which we can do using Chapter 2 ideas. First we convert 50in to meters, then we find the initial velocity knowing that while in the air the acceleration is just due to gravity.

$$50in \times \frac{0.0254m}{1in} = 1.27m$$
$$v^2 = v_0^2 + 2 \times a \times \Delta x$$
$$0 = v_0^2 - 2(9.8m/s^2)(1.27m)$$
$$v_0 = \sqrt{2(9.8m/s^2)(1.27m)}$$
$$v_0 = 5m/s$$

Now that we know his initial velocity we can find the acceleration by $a = \frac{v}{t} = \frac{5m/s}{.05s} = 100m/s^2$. And, finally, knowing the acceleration we find the force with equation 1.

$$\Sigma F = m \times a = 95kg \times 100m/s^2 = 9500N$$
$$F_{legs} + F_g = 9500N$$
$$F_{legs} + 95kg \times (-9.8m/s^2) = 9500N$$
$$F_{legs} = 10400N$$

5. In the movies you often see people jump out of helicopters, buildings, etc, and grab onto a rope a couple meters away. Let's say a person of mass 70kg jumps out of a helicopter with a horizontal velocity of 7m/s to a rope 3m away. If they want to stop themselves within .01m once they grab the rope, what upward force must their hands be able to apply in order to stop themselves from falling?
Ans) We want to know the force the hands apply. To find this, we need to know the acceleration. To find the acceleration, knowing the distance covered, we must know velocity, and we can find that velocity by figuring out how long it took the person to cover the 3m distance to the rope. So, to begin, we draw a free body diagram.



Now, using the fact that there is no acceleration in the x-direction, we can use our kinematic equations to find the amount of time the person fell.

$$x = x_0 + v_0 \times t + 1/2 \times a \times t^2$$
$$3m = 0m + 7m/s \times t + 0$$
$$t = .43s$$

Knowing this time, we can now work in with the y-components (remember, time is really the only thing you can go back and forth with).

$$v = v_0 + a \times t$$
$$v = 0 - 9.8m/s^2 \times (.43s)$$
$$v = -4.2m/s$$

Note that this makes sense because the person is falling and thus has a negative velocity. This is the velocity the person will have in the y-direction when they catch the rope. Now, we want to find the total force required to stop before the person falls .1m. We can find the acceleration knowing the velocity and distance:

$$0^2 = (-4.2m/s)^2 + 2 \times a \times .1m$$
$$a = 88.2m/s^2$$

Note that in this case the acceleration we are talking about is from the hands, which is why, even though we are working in the y-direction, it is not g. Now that we have this number, we can use the sum of forces equation to solve for the force from the hands.

$$\Sigma F = m \times a$$
$$F_{hands} + F_g = m * a$$
$$F_{hands} - 70kg \times 9.8m/s^2 = 70kg \times 88.2m/s^2$$
$$F_{hands} = 6900N$$