Problem Set 2
Physics, summer 2020/21

1) **(2p.)** If a 5-kg bowling ball is projected upward with a velocity of 2.0 m/s, then what is the recoil velocity of the Earth (mass = 6.0 x 10^{24} kg).

Answer:
Since the ball has an ***upward momentum of 10 kg*m/s****, the Earth must have a downward momentum of 10 kg*m/s. To find the velocity of the Earth, use the momentum equation, p = m*v. This equation rearranges to v=p/m. By substituting into this equation,*

*v = (10 kg*m/s)/(6*10^{24} kg)*
v = 1.67*10^{-24} m/s *(downward)*

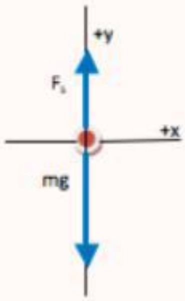
Another way to write the velocity of the earth is to write it as
0.00000000000000000000000167 m/s

2) **(2p.)** A halfback (m = 60 kg), a tight end (m = 90 kg), and a lineman (m = 120 kg) are running down the football field. Consider their ticker tape patterns below. Compare the velocities of these three players.
   a) How many times greater are the velocity of the halfback and the velocity of the tight end than the velocity of the lineman?
   b) Which player has the greatest momentum? Explain.

Lineman → . . . . v=3 m/s
Tight End → . . . . v=______ m/s
Halfback → . . . . v=______ m/s

Answer:
   a) *The tight end travels twice the distance of the lineman in the same amount of time. Thus, the tight end is twice as fast (vtight end = 6 m/s). The halfback travels three times the distance of the lineman in the same amount of time. Thus, the halfback is three times as fast*
   (vhalfback = 9 m/s).
   b) *Both the halfback and the tight end have the greatest momentum. The each have the same amount of momentum - 540 kg*m/s. The lineman only has 360 kg*m/s.*

3) **(2p.)** You are standing on a scale in an elevator on the 4th floor of the science building. As the elevator begins to descend to the first floor, you notice that the scale reads only 85% of your weight. What is the acceleration of the elevator during that period of time? Draw free body diagram.

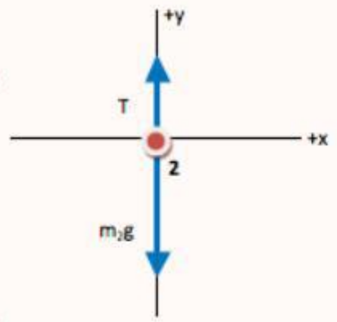


$$\Sigma F = ma$$
$$\Sigma F_y = ma_y$$
$$F_s - mg = ma_y$$
$$0.85\ mg - mg = ma_y$$
$$0.85g - g = a_y$$
$$(0.85 - 1)(9.8\ m/s^2) = a_y$$
$$-1.5\ m/s^2 = a_y$$

Acceleration (your acceleration is the same as the elevator's since you move together) is the quantity that was requested in the problem and so no further mathematical steps are needed. Note that the problem would have been worked in exactly the same way if acceleration was given and the reading of the scale was requested.

4) **(4p.)** A 15 kg block rests on an inclined plane. The plane makes an angle of 25^o with the horizontal, and the coefficient of friction between the block and the plane is 0.13. The 15 kg block is tied to a second block (mass=38 kg) which hangs over the end of the inclined plane after the rope passes over an ideal pulley. What is the acceleration of each of the two blocks, and what is the tension in the rope? Draw free body diagram.

One of the keys to successfully solving a multi-object problem algebraically is to keep track of the variables. I used different symbols for the masses of the two blocks because they are not the same, but I used the same symbol for acceleration because they move together. I also used the same symbol for tension on each block.
At this stage in the problem, we have two unknowns, a and T, and two unsolved equations:
T – 370 N = -(38 kg)a
T – 79 N = (15 kg) a
One approach that always works is to solve one equation for one of the variables and substitute it into the other.
T = 370 N – (38 kg)a from the first equation
370 N – (38 kg)a - 79 N = (15 kg) a substituting into the second
290 N = (38 kg + 15 kg)a
5.5 m/s2=a
Now that you have solved for one of the unknown variables, substitute it into either of the original equations to solve for the other variable. I will substitute it into the second equation.
T – 79 N = (15 kg)(5.5 m/s2)
T = 79 N + 83 N = 160 N
Tension in the rope and acceleration of the blocks are the only information requested in this problem. No further mathematical solution is necessary.



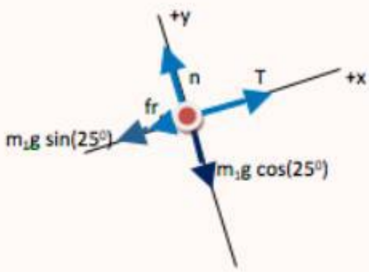
$\Sigma F = ma$

$\Sigma F_y = m_2\, a_{2y}$

$T - m_2 g = m_2(-a)$

$T - (38\ kg)(9.8 m/s^2) = -(38\ kg)a$

$T - 370\ N = -(38\ kg)a$



$\Sigma F_x = m_1\, a_{1x}$

$T - fr - m_1 g\ sin(25^0) = m_1\, a$

$T - \mu n - m_1 g\ sin(25^0) = m_1\, a$

$T - (0.13)(130) - (15kg)(9.8\ m/s^2)\ sin(25^0) = (15\ kg)\ a$

$T - 17\ N - 62\ N = (15\ kg)\ a$

$T - 79\ N = (15\ kg)\ a$

$\Sigma F = ma$

$\Sigma F_y = m_1\, a_{1y}$

$n - m_1 g\ cos(25^0) = 0$

$n - (15\ kg)(9.8\ m/s^2)\ cos(25^0) = 0$

$n = 130\ N$

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