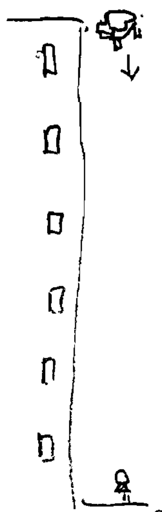
Physics 100 HW 3 (Due 1/31/07) Name S. Olsen



1. An evil villain drops a $m = 300$ kg piano from a 100 m ($= H$) high rooftop aimed at an unsuspecting physics 100 student standing on the sidewalk below. In an attempt to save the student, the incredible *physics-man*, whose mass is 85 kg, jumps upward toward the piano and tries to stop it just before it reaches the ground.

   a) What is the gravitational *potential energy* of the piano when it is at the top of the building? Grav. $PE = mgh = 300\,kg \cdot 10\,m/s^2 \cdot 100\,m = 3.0 \times 10^5\,J$

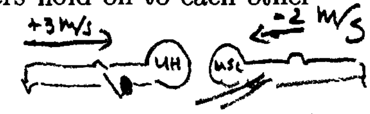
   b) What is the piano's *kinetic energy* just before it hits the ground?
   $\text{Grav } PE_{top} \longrightarrow KE_{bottom} \Rightarrow KE = 3.0 \times 10^5\,J$

   c) What is the piano's speed just before it hits the ground?
   $\frac{1}{2}mv^2 = KE \Rightarrow v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 3 \times 10^5\,J}{300\,kg}} = 44.7\,m/s = V_{piano}$

   d) How fast does *physics-man* have to be going in order to have enough *momentum* to stop the piano? His momentum has to be (at least) equal but opposite the piano's.
   $m_{phys}V_{phys} = -M_{piano}V_{piano} \Rightarrow V_{phys} = \frac{M_{piano}V_{piano}}{m_{phys}} = -\frac{300\,kg \times 44.7\,m/s}{85\,kg} = -158\,m/s$ ← upward

2. Consider a movie directed by Isaac Newton with a script where a good guy leaning against a window in a high rise office building shoots a bad guy who is leaning against a similar window on the other side of the room. The impact of the bullet causes the bad guy to smash through the window and fall to his death. What do you think Isaac Newton would have happen to the good guy? Isaac Newton would probably insist that the good guy recoil with equal but opposite momentum and, therefore, crash through the window he (the good guy) is leaning against and fall to his death. (Short movie)

3. A 90 *kg* UH Warrior fullback, dives for the goal line at 3.0 *m/s*. Just as he is about to cross the goal, he collides headon and in midair into a diving 120 *kg* USC lineman travelling at 2.0 *m/s* in the opposite direction. After the collision the two players hold on to each other and move together. Use conservation of momentum



   a) What is their common speed immediately after the collision?
   initial momentum = final momentum
   $m_{UH}V_{UH} + M_{USC}V_{USC} = (M_{UH} + M_{USC})V_{final}$
   $90\,kg \cdot 3\,m/s - 120\,kg \cdot 2\,m/s = +30\,kg\,\frac{m}{s} = 210\,kg \cdot V_{final} \Rightarrow V_{final} = \frac{+30\,kg\,\frac{m}{s}}{210\,kg} = +0.14\,m/s$

   b) Does the fullback cross the goal line?
   Yes. V_{final} is positive $\Rightarrow$ same as UH player's orig. dir.

4. A considerate physics teacher lifts a 25 *kg* backpack to a height of 1.5 *m* and helps his dutiful wife strap it to her back. She then carries it on a 10 *km* hike over level ground.

   a) How much work does the physics teacher do?
   $W = Fd_{\parallel} \Rightarrow F = mg$; upward, $d_{\parallel}$ = change in $h = +1.5\,m$
   $W = mgh = 25\,kg \cdot 10\,m \cdot 1.5\,m$
   $W = 375\,J$

   b) How much work does the wife do?
   here $F = mg$ but $d_{\parallel} = 0 \Rightarrow W = 0$

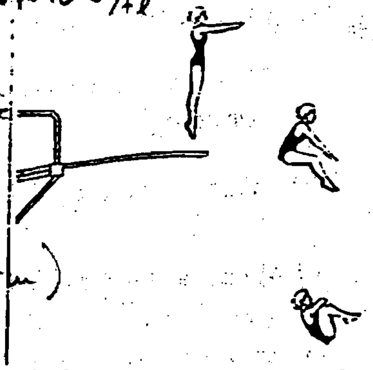
5. An $m = 90\ kg$ physics teacher drinks a six-pack of (lite) beer while watching the UH-USC football game and then decides to climb stairs to work it off. If a six-pack of beer has 1200 Kilocalories (5×10^6 joules) and each flight of stairs is $3.0\ m$ high, how many flights of stairs must he climb to do an amount of work equal to the energy content of the beer he consumed? $W_{1 flight} = mgh = 90kg \cdot 10 m/s^2 \cdot 3m = 2.7 \times 10^3 J/fl$

Total $W = n_{flight} \cdot W_{1 flight}$

$n_{flights} = \frac{\text{Total } W}{W_{1 flt}} = \frac{5 \times 10^6 J}{2.7 \times 10^3 J/flight} = 1850$ flights

6. When high divers want to do a number of flips, they pull their arms and legs in close to their chest. Why?

This reduces their moment-of-inertia I. Since $I\omega$ = constant (conserv. of ang. momentum) ω increases, i.e. they spin faster



7. For this question you have to remember that motion in a circle at a constant speed v corresponds to an acceleration of magnitude $a = v^2/r$ that is directed toward the center of the circle, where r is the radius of the circle.
Newton's laws are only supposed to work in an inertial reference frame, which is a frame that is not accelerating. However, they work well here on Earth, even though we are orbiting the Sun. Because of this orbital motion, an observer on the Earth moves in one full circle every year and is, therefore, accelerating. The radius of the Earth's orbit is $1.5 \times 10^{11}\ m$.

a) What is the speed of the Earth due its motion around the Sun?

$$V_E = \frac{dist}{time} = \frac{2\pi r}{1 yr} = \frac{2 \times 3.14 \times 1.5 \times 10^{11} m}{3.15 \times 10^7 s} = 3 \times 10^4 m/s$$

b) What is the magnitude of the acceleration of an observer on the Earth due to the Earth's orbital motion.

$$a_E = \frac{V_E^2}{r} = \frac{(3 \times 10^4 m/s)^2}{1.5 \times 10^{11} m} = \frac{9 \times 10^8 m^2/s^2}{1.5 \times 10^{11} m} = 6.0 \times 10^{-3} m/s$$

c) What is its direction?

toward the Sun

d) How does it compare to $g = 10m/s^2$, the acceleration of gravity? (ie much bigger? much smaller? about the same?)

much smaller

8. If someone wants to travel to another star, and get there in less than a normal human lifetime, she would need a spaceship that travelled at a speed near that of light (3×10^8 m/s). What kinetic energy would a 10^4 kg (10 ton) spaceship have if it were travelling at *half* the speed of light? $KE = \frac{1}{2} m v^2 = \frac{1}{2} \cdot 10^4 kg \times (1.5 \times 10^8 m/s)^2$

$= 1.1 \times 10^{20} J$

$v = \frac{3 \times 10^8 m/s}{2} = 1.5 \times 10^8 m/s$

How does this compare to the total amount of energy used by the whole world in a year, which is about 2×10^{20} Joules?

More than ½ the world's total annual consumption of Energy.