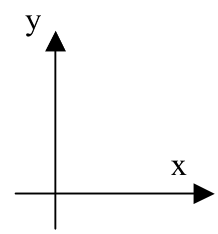
Spring 2001 Physics 2048 Test 2 solutions

Problem 2 (Estimation Problem: 15 points)

You have joined a volunteer fire department. They are looking to buy a new rescue net because the old one broke. (A rescue net is the circular trampoline-like net firemen hold to catch people falling from building.) The cost increases dramatically with the strength of the net and your fire department has a very limited budget. You need to buy the cheapest rescue net that meets your department's needs. Assuming that the force exerted by the net is constant, what is the maximum force the rescue net would need to withstand? Remember the idea is to stop people before they hit the ground.

SOLUTION:



- Maximum fall will be from the top of 5 stories.
- Both initial and final velocities are zero.
- Break motion into two parts
  - Person falling straight down in free fall and speeding up
  - Person slowing down while in contact with the rescue net
  - Maximum speed is right before falling person hits the net

Assumptions

- Maximum weight of person = 400 lb
  At 2 lb./kg, maximum mass m = 400 lb * 1 kg/lb. = 200 kg
  (This large mass is your safety factor, so let's double it)
  m = 400 kg
- Assume net is held 1 meter and a few cm above the ground, h = 1.05 m
- A room in a multistory building is typically 8-12 feet or 3-4 m tall. Let's say there is another meter between the ceiling of one floor and the floor on the next floor up. Thus each story takes up 5 m in height and a person falling from the top of the building will fall 5 stories * 5m/story = 25 m, y_0 = 25 m above the ground

Use kinematics to find the acceleration needed to bring the falling person to a stop with the net before they hit the ground. Use Newton's 2nd law to find the net force and then to find the force exerted by the net on the person.

- Find the speed of the falling person before they hit the net v_1 = ?, a_1 = -- g = -- 9.8 m/s^2

Use the kinematics equation for velocity as a function of displacement and acceleration to find v_1

$v_1{}^2 = v_i^2 + 2a\Delta y$ with initial velocity = 0 m/s, a = -9.8 m/s^2, and

$\Delta y_1 = y_1 - y_i =$ 1.05 m – 25m = -23.95 m

$$v_1 = -\sqrt{0^2 + 2a\Delta y} = \sqrt{2(-g)\Delta y_1} = \sqrt{-2g\Delta y_1}$$

$v_1 = -\sqrt{-2\,(9.8\,m/s^2)(-23.95m)}$ = -- 21.67 m/s (downward)

- Find the acceleration needed to bring the person to a stop before they hit the ground a_2

Use $v_2^2 = v_1^2 + 2a_2\Delta y_2$

$$2a_2\Delta y = v_2^2 - v_1^2$$

$a_2 = \dfrac{v_2^2 - v_1^2}{2\Delta y_2} = \dfrac{(0m/s)^2 - (-2g\Delta y_1)}{2\Delta y_2} = \dfrac{g\Delta y_1}{\Delta y_2} = \dfrac{(9.8m/s^2)(23.95m)}{1.0m}$ = 234.7 m/s^2

- Use Newton's 2[nd] law to find the force exerted by the net on the person

$$a_2 = \frac{1}{m}\Sigma F_{\rightarrow fallingperson} = \frac{1}{m}(\vec{W}_{earth\rightarrow person} + \vec{F}_{net\rightarrow fallingperson})$$

$$\left|\vec{F}_{net\rightarrow person}\right| - \left|\vec{W}_{earth\rightarrow person}\right| = m_{person}\, a_2$$

$$\left|\vec{F}_{net\rightarrow person}\right| = m_{person}\, a_2 + \left|\vec{W}_{earth\rightarrow person}\right| = m_{person}\left(\frac{g\,\Delta y_1}{\Delta y_2}\right) + m_{person}\, g = m_{person}\, g\left(1 + \frac{\Delta y_1}{\Delta y_2}\right)$$

$$\left|\vec{F}_{net\rightarrow person}\right| = (400kg)(9.8m/s^2)\left(1 + \frac{23.95m}{1m}\right) = 98{,}000 \text{ N}$$
