

~~Nov 12~~

~~Hour One: Problem Solving Session 17: Angular Momentum~~

~~Problem Set 10: Due Tues Nov 16 at 4:00 pm.~~

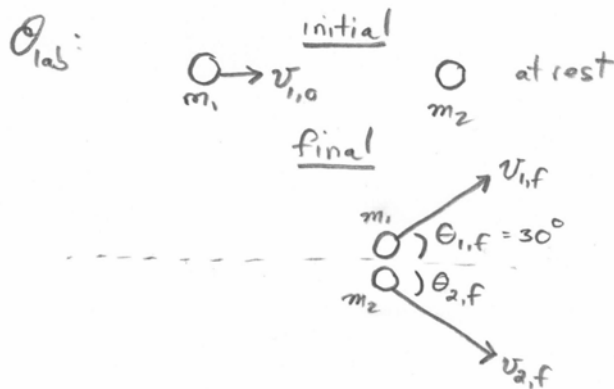
Problem 1: Impulse and Momentum

The compressive force per area necessary to break the tibia in the lower leg, is about $F/A = 1.6 \times 10^8 \text{ N} \cdot \text{m}^2$. The smallest cross sectional area of the tibia, about 3.2 cm^2 , is slightly above the ankle. Suppose a person of mass $m = 6.0 \times 10^1 \text{ kg}$ jumps to the ground from a height $h_0 = 2.0 \text{ m}$ and absorbs the shock of hitting the ground by bending the knees. Assume that there is constant deceleration during the collision. During the collision, the person lowers his center of mass by an amount $\Delta d = 1 \text{ cm}$.

- What is the collision time Δt_{col} ?
- Find the average force of the ground on the person during the collision.
- What is the average impulse of the ground on the person?
- Will the person break his ankle? How much would you need to lower your center of mass so you do not break your ankle?

~~**Problem 2: Two Dimensional Elastic Collision**~~

~~An object with mass m_1 is initially moving with a velocity $v_{1,0} = 3.0 \text{ m/s}$ and collides elastically with another object of equal mass $m_2 = m_1$ that is initially at rest. After the collision m_1 moves with an unknown speed $v_{1,f}$ at an angle $\theta_{1,f} = 30^\circ$ with respect to its initial direction of motion. After the collision, m_2 moves with an unknown speed $v_{2,f}$, at an unknown angle $\theta_{2,f}$ (see sketch). Find the final velocities of each of the masses and the angle $\theta_{2,f}$.~~



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Fall Term 2004

Problem Set 9: Momentum and Collision Theory : Solutions

Problem 1: Impulse and Momentum

The compressive force per area necessary to break the tibia in the lower leg, is about $F/A = 1.6 \times 10^8 \text{ N} \cdot \text{m}^2$. The smallest cross sectional area of the tibia, about 3.2 cm^2 , is slightly above the ankle. Suppose a person of mass $m = 6.0 \times 10^1 \text{ kg}$ jumps to the ground from a height $h_0 = 2.0 \text{ m}$ and absorbs the shock of hitting the ground by bending the knees. Assume that there is constant deceleration during the collision. During the collision, the person lowers his center of mass by an amount $\Delta d = 1 \text{ cm}$.

- a) What is the collision time Δt_{col} ?
- b) Find the average force of the ground on the person during the collision.
- c) What is the average impulse of the ground on the person?
- d) Will the person break his ankle? How much would you need to lower your center of mass so you do not break your ankle?

a) The speed of the person before touching the ground is $\sqrt{2gh_0}$

If a is the magnitude of the deceleration we must have:

$$a\Delta t_{coll} = \sqrt{2gh_0} \text{ and } \frac{1}{2}a(\Delta t_{coll})^2 = (\Delta t_{coll})\sqrt{\frac{gh_0}{2}} = \Delta d \text{ from which}$$

$$\Delta t_{coll} = \Delta d \sqrt{\frac{2}{gh_0}} = 3.2 \cdot 10^{-3} \text{ s}$$

$$a = \frac{gh_0}{d}$$

b) The average force of the ground on the person is:

$$|F| = m(g + a) = mg \frac{d+h_0}{d} = 118 \cdot 10^3 \text{ N}$$

c) The average impulse of the ground on the person is:

$$|I| = |F|\Delta t_{coll} = 379 \text{ N s}$$

d) the force required to break the tibia is:

$$F_B = (1.6 \cdot 10^8)(3.2 \cdot 10^{-4}) \text{ N} = 51.2 \cdot 10^3 \text{ N}$$

so that the tibia will break (Ouch!)

In order not to suffer the person should lower its center of mass at least of:

$$\Delta d = \frac{mgh_0}{F_b - mg} = 2.3 \text{ cm}$$