Assignment VIII, PHYS 111 (General Physics I)
Fall 2018
Due 11/2/18 at start of class

As always, please put your clearly written answers on separate paper.

1. In class, I argued that a careful treatment of two objects undergoing a one-dimensional elastic collision results in the following relationships:

$$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{1i} + \left(\frac{2m_2}{m_1 + m_2}\right) v_{2i}$$
$$v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1i} + \left(\frac{m_2 - m_1}{m_1 + m_2}\right) v_{2i}$$

   Start from these expressions and show that $v_{2f} - v_{1f} = v_{1i} - v_{2i}$. (This is a really important result in problem-solving. It tells us that if the objects are approaching each other at speed Δv before the collision, then they separate from each other at the same speed Δv after the collision.)

2. A neutron in a reactor makes a collision with the nucleus of a carbon atom initially at rest. (Assume that the nucleus of a carbon atom is initially equal to 12 times the mass of a neutron). (You may need to look up the mass of a neutron – it shouldn't be hard to find). You may assume that this problem is fully 1-dimensional.

   a) If the collision was completely inelastic (in other words, the neutron combines with the carbon nucleus), what fraction of the initial kinetic energy is lost?

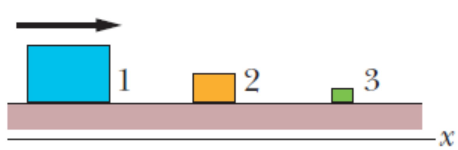
   b) If the collision was perfectly elastic, the what fraction of the neutron's initial kinetic energy was transferred to the carbon nucleus?

3. The figure below shows block 1 (with mass m_1) sliding along the x axis of a frictionless floor with speed $v_{1i} = 4.00$ m/s. Then block 1 undergoes an elastic collision with a stationary block of mass $m_2 = \frac{m_1}{2}$. Next, block 2 undergoes a one-dimensional elastic collision with stationary block 3 having mass $m_3 = \frac{m_2}{2}$.

   a) What then is the final speed of block 3?

   b) What fraction of the initial kinetic energy is transferred to block 3? (In other words, if the initial kinetic energy is K_i, you can write that the final kinetic energy of block 3 as $(K_f)_3 = \gamma K_i$ with γ some constant between 0 and 1. Find γ).

   c) What fraction of the initial momentum is transferred to block 3? (In other words, if the initial momentum is p_i, you can write the final momentum of block 3 as $(p_f)_3 = \beta p_i$ with β some constant. Find β).

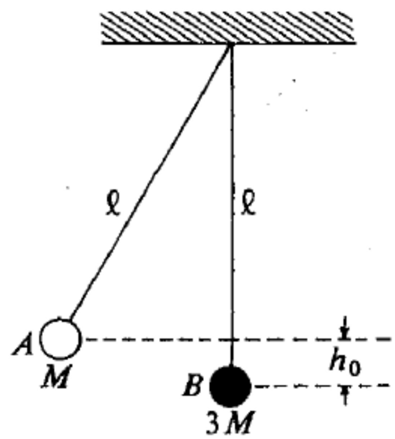


4. During the battle of Gettysburg, the gunfire was so intense that several bullets collided in midair and fused together. Assume a 5.50 g Union musket ball moving to the right at 290 m/s and 24.0° above the horizontal collies with a 3.75 g Conferate ball moving to the left at 312 m/s and 14.0° above the horizontal. In this problem, ignore any effects of gravity.

   a) Immediately after the musket balls collide, what was the velocity of the fused-together bullet?

   b) What portion (aka what fraction or what percentage) of the initial kinetic energy was lost in the fusing-together process?

5. Two small spheres of putty, A and B of masses M and $3M$ respectively, hang from the ceiling on strings of equal length ℓ. Sphere A is drawn aside so that it is raised to h a height $h_\circ$ as shown below and then released. Sphere A collides with sphere B and then they stick together and (while attached to each other) swing to a maximum height h, when the two spheres are momentarily at rest. What is h in terms of $h_\circ$?



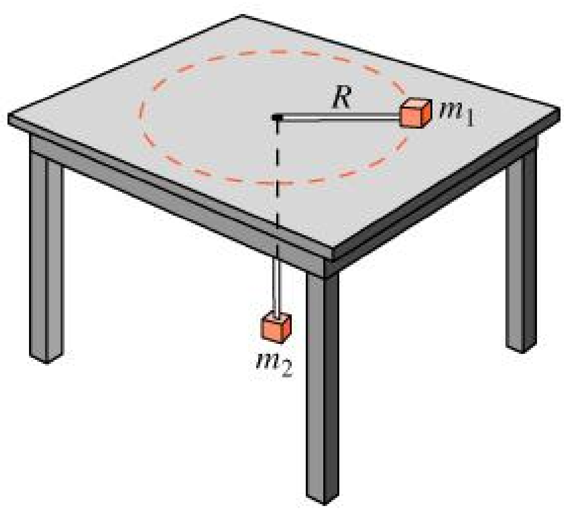
6. A misbehaving car engine starts idling fast, at 1100 rpm (rotations per minute or, equivalently, revolutions per minute). If, after turning the car off, the engine stops running completely in 0.9 seconds, what is the rotational acceleration of the engine during this "turning-off" process? You may assume α is constant.

7. If a ball of mass m makes a glancing elastic collision with another initially stationary ball of mass m, I stated in class that the trajectories of the two balls post-collision always move off at trajectories at an angle of 90° from each other. (I call this the billiard-ball corollary). In this problem, you are going to show this. I'll get you started. Let the initial ball move in the +x direction at initial speed $v_\circ$. After the collision, this ball moves at speed v_f at an angle θ with respect to its initial trajectory. For simplicity, I'll let θ be aligned so that the ball begins to have a positive y velocity. The other ball moves at speed v' at an angle ϕ with respect to the other ball's initial trajectory. This is a positive angle, but directed with a component in the negative y direction. Thus, using conservation of momentum in the x and y directions and conservation of energy, we get the following relationships:

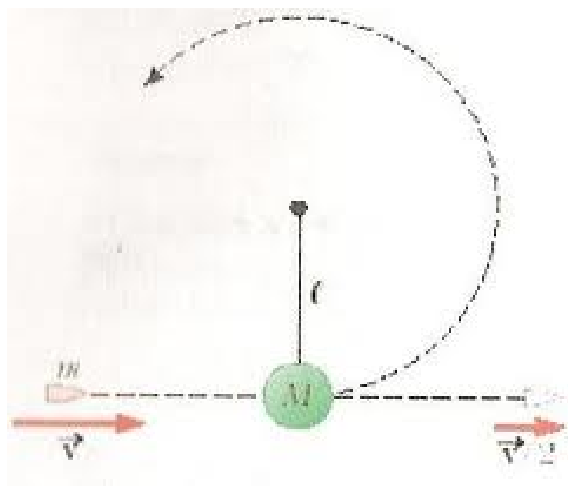
$$p_x : mv_\circ = mv_f \cos\theta + mv' \cos\phi$$
$$p_y : 0 = mv_f \sin\theta - mv' \sin\phi$$
$$E : \frac{1}{2}mv_\circ^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}m(v')^2$$

Your goal is to prove that $\theta + \phi$ must equal 90° (or, if you are practicing your Physics units, $pi/2$ radians). Hints: divide the momentum equations by m and multiple the E equation by $2/m$. After that, you can start getting the p equations closer to the E equation by squaring and adding them.

8. A block of mass m_1 slides in a circular path of radius R on a frictionless table. The mass is connected via an inextensible massless string to a mass m_2 hanging (at fixed height) below the table. What is the speed of m_1?



9. A bullet of mass m and initial speed v passes completely through an initially stationary mass at the end of a (massless) string with the mass at the bottom having mass M and the string having length ℓ. The bullet emerges with speed αv. (α is an unspecified constant somewhere between 0 and 1). What is the minimum value of v such that the mass will barely swing through a complete vertical circle? (Note, the picture below assumes $\alpha = \frac{1}{2}$, but I want to do a more general problem here – the speed coming out should be αv, not necessarily $v/2$.)



10. Normally, I like to give my classes the opportunity to fill out an evaluation form for me somewhere around the mid-semester mark. This allows me to potentially make changes to the course while you're still here, rather than waiting until the end-of-semester evaluation time when – even if I make improvements to my courses – you don't get to see the benefit of the changes. Because of the hurricanes this semester I hesitate to use class-time to fill out mid-semester evaluations – but I do think they can be quite impactful and useful. As such, please let me know if there are any elements of this class you either would like to see changed/improved and/or if there are things you really appreciate. I can't promise to accommodate all requests (we have a lot of content to get through, and often student suggestions contradict each other) – but I will promise that I'll give any comments you write to me serious consideration. If you aren't comfortable offering your feedback here (where your comments are not anonymous), please feel free at any time to slip a note under my office door. I take student feedback extremely seriously, so please let me know what else I can do to help aid you in your learning process.