

Exam 1 – Force and Momentum

September 27, 2012

This is a closed book examination. You may use a both sides of a 3"x5" notecard (or one side of a 4"x6" notecard) with equations, concepts or other soothing sonnets. There is extra scratch paper available. Your explanation is worth ¾ of the points. Explain your answers!

A general reminder about problem solving:

1. Draw a picture then create a simplified free body diagram with all forces
2. Write down what you know including coordinate frame
3. Write down what you don't know and/or want to know
4. List mathematical relationships
5. Simplify and solve
6. Check your answer – Is it reasonable? Are units correct?
 - Show all work!

1. [12 PTS] You are driving your truck down the street at exactly the speed limit on the way to your physics exam. Approaching a stop sign you apply a constant braking force. As soon as the truck is stopped you put the truck in reverse (since you realize you forgot your physics notecard) and back up at a constant acceleration till you reach the speed limit. The magnitude of your braking acceleration is twice your truck's reverse acceleration. Neglecting friction, draw $x(t)$, $v_x(t)$ and $a_x(t)$ for your truck. Completely label your graphs and indicate when the truck is stopped and when the truck is moving at a constant velocity on each graph.



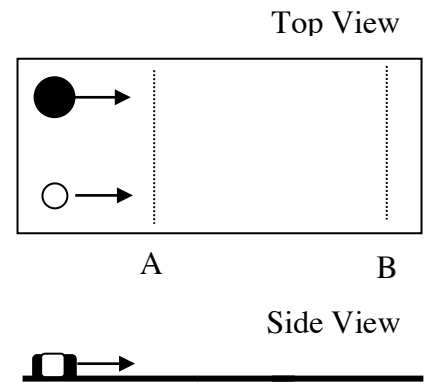
2. [4 PTS] Recently the international space station (ISS) was moved into a higher altitude orbit around the earth (roughly 400 km). Many objects appear to float inside the ISS – that is they are stationary with respect to the ISS. What is the gravitational acceleration of an object inside the ISS (with respect to the Earth)? Explain.
- a) Exactly 9.81 m/s^2
 - b) Obviously zero (0 m/s^2)
 - c) Greater than 9.81 m/s^2
 - d) Less than 9.81 m/s^2
 - e) Depends on the mass of the object
3. [4 PTS] A deer runs out of the woods and hits the side of your car. The deer is much less massive than your car. It follows that the force the car exerts on the deer
- a) is greater in magnitude than the force the deer exerts on the car.
 - b) is the same magnitude that the force the deer exerts on the car.
 - c) is smaller in magnitude than the force the deer exerts on the car.
 - d) can not be compared to the force the deer exerts on the car unless you know the angle of impact.

You throw a heavy small blue ball as hard as you can straight up into the air. Assume up is the positive direction and ignore air drag. The next three questions refer to this ball after it has left your hand. Please explain your answers (your explanation is worth $\frac{3}{4}$ of the points).

4. [4 PTS] The acceleration of the ball on the way up is
- a) 9.81 m/s^2 in the upward direction.
 - b) zero (no acceleration).
 - c) 9.81 m/s^2 in the downward direction.
 - d) Can not tell. It depends on the initial momentum.
5. [4 PTS] The momentum of the ball on the way up is
- a) positive (in the upward direction).
 - b) zero.
 - c) negative (in the downward direction).
 - d) Can not tell. It depends on the initial position.
6. [4 PTS] The acceleration of the ball at the very top of its throw (just before it starts back down) is
- a) 9.81 m/s^2 in the upward direction.
 - b) zero (no acceleration).
 - c) 9.81 m/s^2 in the downward direction.
 - d) Can not tell. It depends on how high it was thrown.

7. [4 PTS] Two objects are dropped from a hot air balloon. The objects are identical except object B has more mass than object A ($m_B > m_A$). Object A reaches terminal velocity much faster than object B. It follows that the force due to air drag on object A is
- greater than the force due to air drag on object B
 - the same as the force due to air drag on object B
 - smaller than the force due to air drag on object B
8. [4 PTS] A spring with a mass attached is hanging from a stand and oscillating with a period of 4 seconds. Which of the following would decrease the period to 2 seconds.
- Double the mass so $m_{\text{new}} = 2 m_{\text{old}}$
 - Attach an identical spring in parallel
 - Attach an identical spring in series
 - Decrease the mass so $m_{\text{new}} = \frac{1}{4} m_{\text{old}}$
 - Double the mass so $m_{\text{new}} = 2 m_{\text{old}}$ and attach an identical spring in parallel

The next two questions refer to the diagram to the right and involve two disks. The disks, both initially at rest, are pushed with the same force for the same amount of time along a level surface. The push stops before either disk reaches line A. The black disk has twice the mass of the white disk. Assume that the surfaces are frictionless.



9. [4 PTS] Which disk has a greater change in momentum when it crosses line B?
- The white disk has a greater change in momentum.
 - The black disk has a greater change in momentum.
 - Both disks have the same change in momentum.
 - Not enough information.
10. [4 PTS] Which disk is traveling at a greater velocity when it crosses line B?
- The white disk is traveling at a greater velocity.
 - The black disk is traveling at a greater velocity.
 - Both disks have the same velocity.
 - Not enough information.

Please do the next two problems on additional paper or on problem solving sheets.

11. [12 PTS] At a highway intersection a blue car (mass = 2800 kg) collides with a silver pick-up truck (mass = 4700 kg). After the collision the car and truck slide along stuck together. The truck has a GPS unit that records its velocity. The truck's velocity just before the collision was $\langle -14, 0, 29 \rangle \frac{m}{s}$. After the collision the velocity of the stuck-together car and truck is $\langle 6.2, 0, 18.2 \rangle \frac{m}{s}$. The speed limit on both highways is 75 mph. Determine the car's velocity just before the collision. Was either the car or truck speeding? (Note: 1 mile = 1609 meters)
12. [12 PTS] Suppose that you are navigating a spacecraft far from other objects. The mass of the spacecraft is 1.5×10^5 kg (about 150 tons). The rocket engines are shut off and you are coasting along with a constant velocity of $\langle 0, 20, 0 \rangle \frac{km}{s}$. As you pass the location $\langle 1208, 1.5 \times 10^4, 2000 \rangle km$ you briefly fire side thruster rockets so that your spacecraft experiences a net force of $\langle 8.8 \times 10^4, 0, 0 \rangle N$ for 1 minute. You then continue coasting with the all rocket engines turned off. Assume the ejected gases have a mass that is small compared to the mass of the spacecraft. Determine your spacecraft's position and velocity 50 minutes after the side thruster rockets are finished firing. (Note: 1 km = 1000 m)

Possibly useful mathematical relationships:

$$\begin{aligned}\sin^2(\theta) + \cos^2(\theta) &= 1 & \sin(2\theta) &= 2 \sin(\theta) \cos(\theta) \\ \cos(2\theta) &= \cos^2(\theta) - \sin^2(\theta) & &= 2 \cos^2(\theta) - 1 = 1 - 2 \sin^2(\theta)\end{aligned}$$

Derivative of a polynomial $\frac{d}{du} Cu^n = nCu^{n-1}$ The Chain Rule $\frac{d}{dz} f(u) = \frac{d}{dz} u \frac{d}{du} f(u)$

Anti-derivative (integral) of a polynomial $\int Cu^n du = \frac{1}{n+1} Cu^{n+1} + const.$

Useful Data:

Mass of Earth = 6×10^{24} kg

Radius of the Earth = 6.4×10^6 m

$G = 6.67 \times 10^{-11}$ Nm²/kg²

Acceleration due to gravity at the surface of the earth is 9.81 m/s²