PHYS 2240 Exam I

Thursday, March 11, 2021

> ***Instructions***: *You have as much time as you need to complete this exam. Take a deep breath and relax! Read each question carefully, and let me know if anything is unclear. Partial credit may be awarded, so you are encouraged to clearly and legibly show your work for each problem. Extra paper is available at the front of the room if you need it. Write your name on every extra sheet you use, and clearly label what problem you are working on. Staple this to the back of your exam when you turn it in. You may use any information contained within this exam, as well as a calculator.*
> *Good luck!*

Name: ______________________________

MAY THE

$$\frac{d}{dt}(\overrightarrow{mv})$$

BE WITH YOU!

Potentially Useful Information

$$\vec{F}_{grav} = -G\frac{m_1 m_2}{|\vec{r}|^2}\hat{r}$$

$\left|\vec{F}_{grav}\right| \approx mg$ near Earth's surface

$$\vec{F}_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|^2}\hat{r}$$

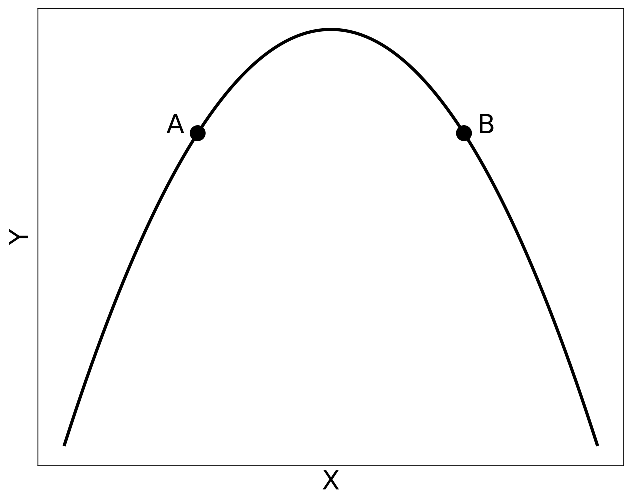
$\left|\vec{F}_{spring}\right| = k_s s$ opposite to the stretch

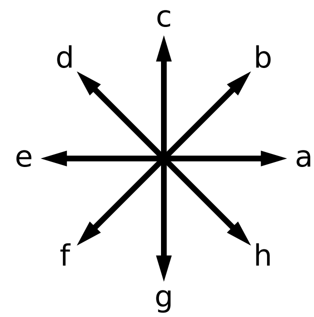
$\hat{f} = \langle \cos\theta_x, \cos\theta_y, \cos\theta_z \rangle$ unit vector from angles

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N $\cdot$ m^2/kg^2
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N $\cdot$ m^2/C^2
Proton charge	e	1.6×10^{-19} C
Avogadro's number	N_A	6.02×10^{23} atoms/mol

milli	m	1×10^{-3}	kilo	K	1×10^3
micro	μ	1×10^{-6}	mega	M	1×10^6
nano	n	1×10^{-9}	giga	G	1×10^9
pico	p	1×10^{-12}	tera	T	1×10^{12}

1. (10 points) A ball moves through the air following the path described in the figure below





(a) Which arrow (a-h) best describes the direction of the ball's average velocity from point A to point B?
○ a ○ b ○ c ○ d ○ e ○ f ○ g ○ h

(b) Which arrow (a-h) best describes the direction of the ball's instantaneous velocity at point B?
○ a ○ b ○ c ○ d ○ e ○ f ○ g ○ h

(c) Which arrow (a-h) best describes the direction of the ball's instantaneous momentum at point A?
○ a ○ b ○ c ○ d ○ e ○ f ○ g ○ h

(d) Which arrow (a-h) best describes the direction of the change in the ball's momentum from point A to point B?
○ a ○ b ○ c ○ d ○ e ○ f ○ g ○ h

(e) Is the ball experiencing an interaction with another object? Explain.

2. (10 points) Over a certain time interval, a ball is moving to the left or the right (or is motionless). The ball is subject to one or many unknown forces.

   (a) If the ball is permanently at rest, which of the following are possible (check all that apply)?
   - ☐ There is a force acting to the right
   - ☐ The net force is zero
   - ☐ There is a net force acting to the right
   - ☐ There is a net force acting to the left
   - ☐ There is a force acting to the left

   (b) If the ball is moving to the right
   - ☐ There is a force acting to the right
   - ☐ The net force is zero
   - ☐ There is a net force acting to the right
   - ☐ There is a net force acting to the left
   - ☐ There is a force acting to the left
   - ☐ The momentum of the ball is changing

   (c) If the ball is moving to the left with increasing speed
   - ☐ There is a force acting to the right
   - ☐ The net force is zero
   - ☐ There is a net force acting to the right
   - ☐ There is a net force acting to the left
   - ☐ There is a net force acting to the left with increasing magnitude
   - ☐ There is a net force acting to the left with decreasing magnitude
   - ☐ There is a force acting to the left
   - ☐ The momentum of the ball is changing

   (d) If the ball is moving to the left at constant velocity
   - ☐ There is a force acting to the right
   - ☐ The net force is zero
   - ☐ There is a net force acting to the right
   - ☐ There is a net force acting to the left
   - ☐ There is a force acting to the left
   - ☐ The momentum of the ball is changing

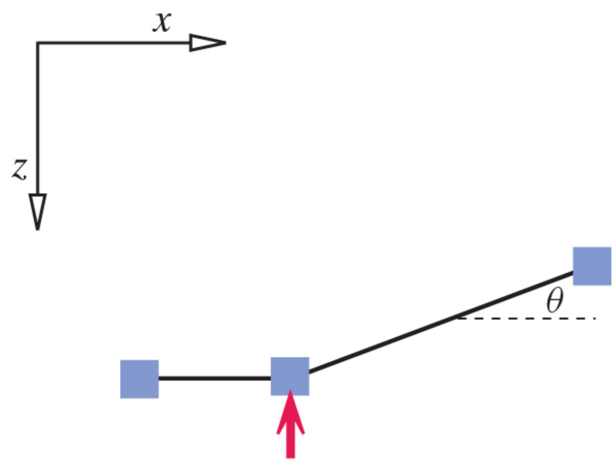
3. (10 points) A 1.5 million kg space shuttle is in outer space and is initially at rest. It then fires its rockets (which exert a constant force of 2×10^7 N) for 30 seconds before shutting them back off. At what speed is the shuttle traveling after this time?

4. Two driverless cars are about to collide at an intersection. One car (with a mass of 1100 kg) is moving from west to east (call this the $+x$ direction) with a speed of 20 m/s. The other car (with a mass of 1500 kg) is moving from south to north (the $+y$ direction) with a speed of 18 m/s. After the cars crash, they remain stuck together.

   (a) (10 points) What is the velocity of the two stuck-together cars just after the collision (ignore friction)? Express your result as a vector.

   (b) (5 points) What angle do the two stuck-together cars move with relative to the x axis after the collision? Express your result in degrees.

5. (15 points) A 0.6 kg block of ice is sliding by you on a very slippery floor at 3.5 m/s. As it goes by, you give it a kick perpendicular to its path. Your foot is in contact with the ice block for 0.002 seconds. The block eventually slides at an angle of $\theta = 24°$ from its original direction. What force did you apply during the kick? Make sure to express your result as a vector.



6. A 54 kg astronaut takes a 10 kg fire extinguisher with her outside to put out a small fire. She sprays the extinguisher for 2 seconds while it exerts a constant force of 50 N. The force pushes the astronaut (who is still carrying the fire extinguisher) backward and away from the ship (Figure 1).

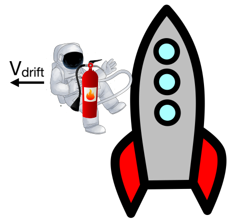


Figure 1: Astronaut and extinguisher drift backward

(a) (10 points) Assuming that the mass of the fire extinguisher hasn't changed, with what speed are the astronaut and extinguisher drifting away from the ship?

(b) (10 points) In an attempt to change her velocity to move back toward the ship, the astronaut throws the 10 kg extinguisher backwards so that it moves at a speed of 15 m/s. After throwing the extinguisher, what direction is her velocity (away from or toward the ship)? What is her speed?

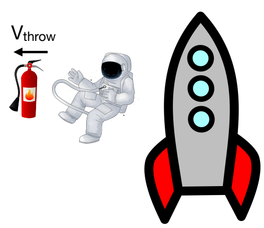
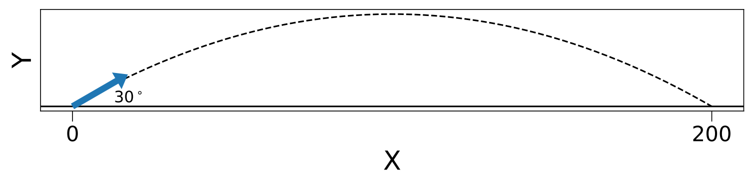


Figure 2: Astronaut throws extinguisher backward

7. (20 points) On Earth, a golfer is able to hit a golf ball so that it travels 200 meters when launched at an angle of 30° to the horizontal (if the ball lands at the same elevation it was hit from). How far could this same golfer hit the ball if the golf course were on the surface of the moon (which has a radius of 1740 km and a mass of 7.3×10^{22} kg). (Assume the golfer swings with the same velocity, the ball is again launched at a 30° angle, and the ball lands at the same elevation it was launched from.)



Question	Points	Score
1	10	
2	10	
3	10	
4	15	
5	15	
6	20	
7	20	
Total:	100	