PHYS 2240 Final Exam

Tuesday, May 4, 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

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

$$\left|\vec{F}_{grav}\right| \approx mg \text{ near Earth's surface} \qquad \Delta U_{grav} \approx mg\Delta y \text{ near Earth's surface}$$

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

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

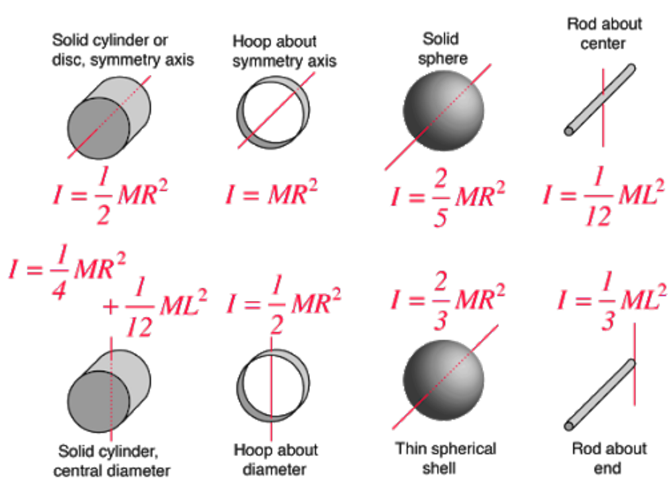
$$\left|\left(\frac{d\vec{p}}{dt}\right)_{\perp}\right| = \frac{pv}{R} \approx \frac{mv^2}{R} \text{ (if } v << c\text{) where } R = \text{radius of kissing circle}$$

$$\omega = \frac{2\pi}{T} \qquad x = A\cos\omega t \qquad \omega = \sqrt{\frac{k_s}{m}}$$

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

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N · 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 · m^2/C^2
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
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. (15 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

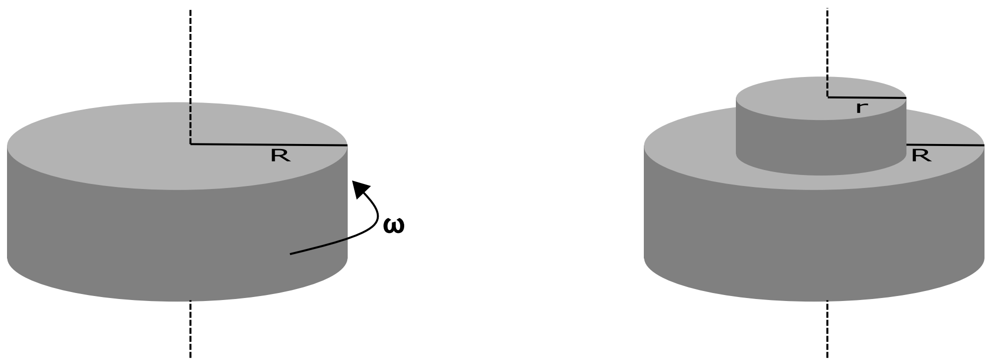
   (c) If the ball is moving to the left with increasing speed

   - ☐ 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

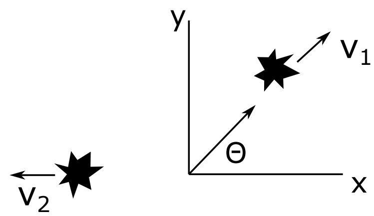
   (d) If the ball is moving to the left at constant velocity

   - ☐ 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

2. (20 points) A uniform-density disk of mass $M = 12$ kg and radius $R = 20$ cm is spinning about its central axis with angular speed $\omega = 30$ rad/sec. A second disk, which is initially not rotating, is then dropped onto the first disk. Friction between the two disks causes the upper disk to begin rotating, and very quickly both disks are rotating together with the same angular speed. What is the final angular speed ω_f, if the second disk has a radius $r = 12$ cm, and a mass $m = 4$ kg?



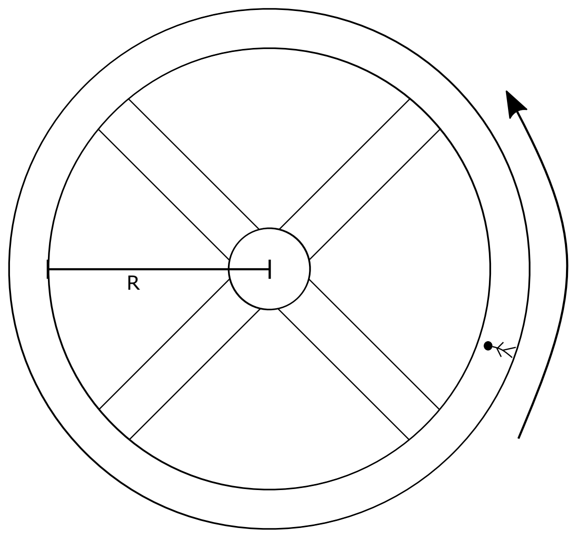
3. (20 points) A 50 gram firecracker is initially at rest when it explodes into three pieces which move away in different directions. Immediately after the explosion, the first piece, which has a mass of 16 grams, moves with a speed of 22 m/s at an angle of $\theta = 60°$ relative to the x axis. The second piece (20 g) moves directly backward with a speed of 14 m/s. These two pieces are illustrated in the figure below.



(a) With what speed and in what direction does the third piece move after the explosion? (Express your direction as an angle relative to the x axis)

(b) The three pieces went from being motionless initially to moving with great speed after the explosion. Was energy conserved in the explosion? Explain.

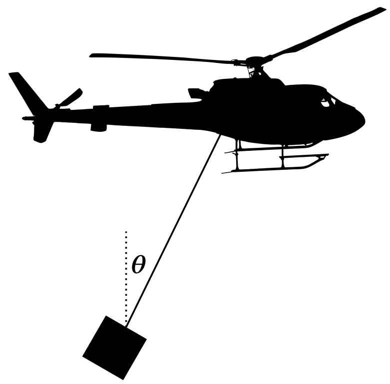
4. A certain interstellar spaceship has a circular shape (as shown in the figure below) so that it can rotate to simulate the effect of gravity. The ship has a radius of 75 m, and a mass of $800,000$ kg. In calculating the motion of the ship, you may make treat it as a large bicycle wheel (assume all of the mass is concentrated around the perimeter, and assume the thickness of the outer shell is very small compared to the radius of the ship).



(a) (10 points) How fast must the ship spin (in rotations per second) so that the apparent weight of a person standing at the perimeter is the same as it would be on Earth?

(b) (10 points) The ship attains this spin by firing rockets on the edge of the perimeter. How much energy must the ship use in order to achieve the rotation rate found in part (a)?

5. A helicopter flies to the right with a constant speed of 12 m/s, just above the surface of the Earth. A 900 kg package is suspended by a cable below the helicopter. The package is moving with the same constant velocity as the helicopter, but the force of the air against the package causes it to lag slightly behind the position of the helicopter, so that the cable makes a slight angle $\theta = 22°$ with respect to the vertical direction.



(a) (5 points) Draw a free-body diagram representing the forces acting on the package

(b) (15 points) The strength of the cable is listed as 9300 N. Is the cable strong enough to support the package under these circumstances?

6. (5 points) Throughout this course, we have discussed three fundamental principles of physics. What are they? Don't just name them, explain them (either mathematically or with words)

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