PHYS 2211 Test 3
Fall 2014

Name(print) Test Key **Lab Section** 

Schatz(N), Bongiorno(M)					
Day	12-3pm	2-5pm	3-6pm	5-8pm	6-9pm
Monday		M01			
Tuesday	M03 N01		M06 N02		N03
Wednesday		M02 N07		M07	
Thursday	M04 N04		M05 N05		N06

Instructions

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- You must show all work, including correct vector notation.
- **Correct answers without adequate explanation will be counted wrong.**
- Incorrect work or explanations mixed in with correct work will be counted wrong. Cross out anything you do not want us to grade
- Make explanations correct but brief. You do not need to write a lot of prose.
- Include diagrams!
- **Show what goes into a calculation, not just the final number, e.g.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^{4}$
- Give standard SI units with your results.

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can not calculate (explain that you are doing this), and use it to do the rest of the problem.

Honor Pledge

"In accordance with the Georgia Tech Honor Code, I have neither given nor received unauthorized aid on this test."

Melvin Van Horne

Sign your name on the line above

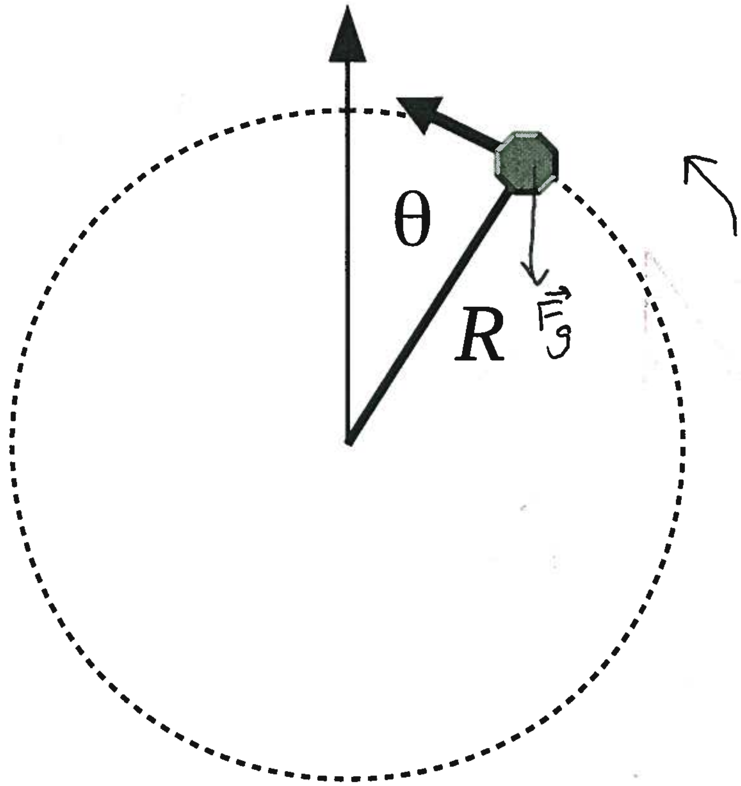
PHYS 2211

Do not write on this page!

Problem	Score	Grader
Problem 1 (25 pts)		
Problem 2 (25 pts)		
Problem 3 (25 pts)		
Problem 4 (25 pts)		

Problem 1 (25 Points)

On the Earth, a rock of mass m is tied to the end of a rope of length R. The rock is swung counterclockwise in a circle of radius R in a vertical plane (gravity points down). Consider the rock when the rope makes an angle of θ with the vertical, as shown in the diagram. At this location, the tension in the rope is a known quantity T and the speed of the rock is decreasing.



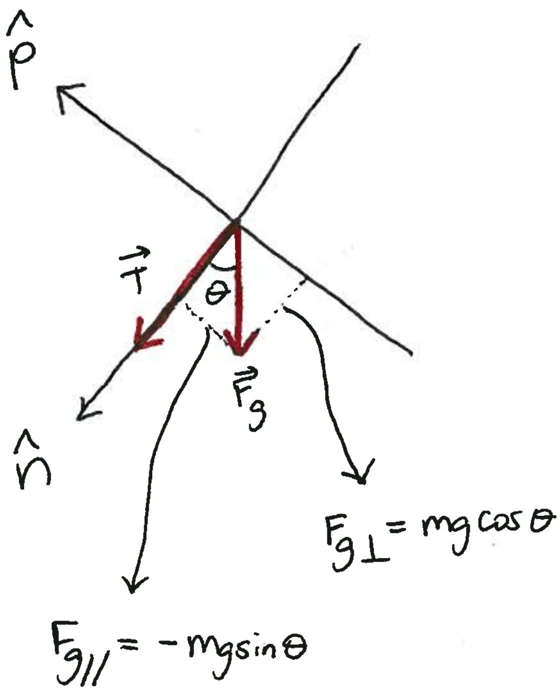
(a 5pts) Is the perpendicular component of the net change in momentum for the rock zero? Explain briefly how you know this.

3pts $\left\{ \left(\frac{d\vec{p}}{dt}\right)_\perp \neq 0 \right.$ because the rock is turning (curving trajectory) $\}$ 2pts

Also: $\left(\frac{dp}{dt}\right)_\perp = \frac{mv^2}{R}$, and $m \neq 0$, $v^2 \neq 0$, $R \neq 0$

(b 5pts) Is the parallel component of the net change in momentum for the rock zero? Explain briefly how you know this.

3pts $\left\{ \left(\frac{d\vec{p}}{dt}\right)_{//} \neq 0 \right.$ because the speed of the rock is changing (decreasing at this location) $\}$ 2pts (c 7pts) Determine the parallel component of the net force on the rock in terms of the known quantities given in the problem statement.



$$\vec{F}_{net\,//} = \vec{F}_{g//} + \cancel{\vec{T}_{//}}^{\,0} =$$

$$= \vec{F}_{g//} =$$

$$= \boxed{-mg\sin\theta\ \hat{p}}$$

$$\begin{bmatrix} -0.5 \\ -1.0 \\ -2.5 \\ -6.5 \end{bmatrix}$$

(d 8pts) Calculate the speed of the rock in terms of the known quantities given in the problem statement.

$$\left(\vec{F}_{net}\right)_\perp = \left(\frac{d\vec{p}}{dt}\right)_\perp$$

$$\vec{F}_{g\perp} + \vec{T}_\perp = \frac{mv^2}{R}\hat{n}$$

$$mg\cos\theta\,\hat{n} + T\hat{n} = \frac{mv^2}{R}\hat{n}$$

$$\frac{R}{m}\left(mg\cos\theta + T\right) = v^2$$

$$\boxed{v = \sqrt{Rg\cos\theta + \frac{RT}{m}}}$$

$$\begin{bmatrix} -0.5 \\ -1.0 \\ -2.5 \\ -6.5 \end{bmatrix}$$

Problem 2 (25 Points)

(a 9pts) A person jumps out of an airplane above the surface of the Earth, and falls a distance h before opening their parachute. Once the parachute is open the person coast to the ground a distance d at constant velocity. For each of the statements below write: **Positive, Negative, Zero, or Insufficient Information to Answer.**

3 each

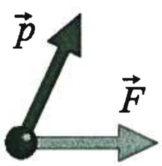
- The work done on the person by the Earth is: POSITIVE
- The change in gravitational potential energy of the person+Earth system is: NEGATIVE
- The work done on the person by the parachute is: NEGATIVE

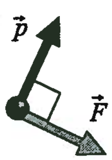
(b 8pts) Pluto orbits the Sun in an elliptical orbit with a period of 249 years. For each of the statements below write: **Positive, Negative, Zero, or Insufficient Information to Answer.**

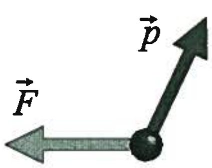
- 2pts During one full period of Pluto, the work done on Pluto by the Sun is: ZERO
- 3pts While Pluto is moving away from the Sun, the work done on Pluto by the Sun is: NEGATIVE
- 3pts While Pluto is moving toward the Sun, the work done on Pluto by the Sun is: POSITIVE

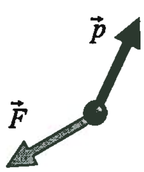
(c 8pts) A particle is moving under the influence of a force in each of the scenarios sketched below. For each case, will the work done in the next instant be: **Positive, Negative, Zero, or Insufficient Information to Answer.**

2pts each

- 

POSITIVE
- 

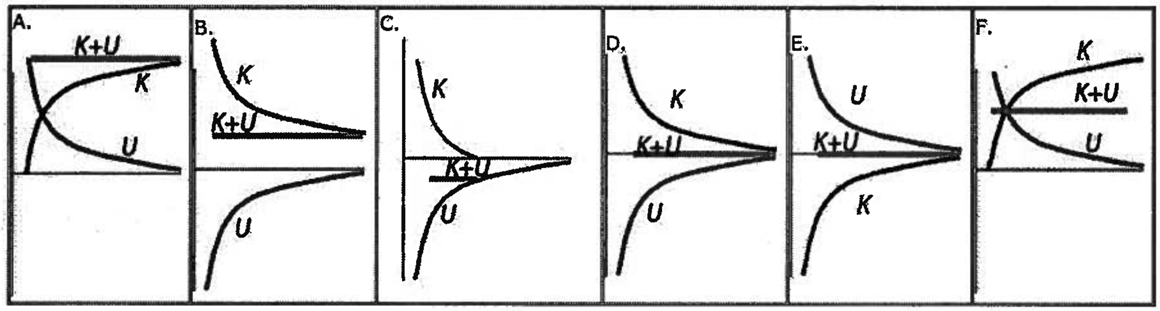
ZERO
- 

NEGATIVE
- 

NEGATIVE

Problem 3 (25 Points)

All



(a 4pts) Which of the diagrams above corresponds to a system of two protons which start out far apart, moving toward each other (that is, their initial velocities are nonzero and they are heading straight at each other)?

Circle one: A B C D E F

(b 3pts) Which of the diagrams above corresponds to a system of a proton and an electron which start out far apart, moving toward each other (that is, their initial velocities are nonzero and they are heading straight at each other)?

Circle one: A B C D E F

(c 4pts) Which of the diagrams above corresponds to a system of a proton and an electron which start out some distance apart, moving away from each other, and reaching zero velocity when they are infinitely far away (that is, their initial velocities are nonzero)?

Circle one: A B C D E F

(d 3pts) Which of the diagrams above corresponds to a system of a proton and an electron which are held at rest at some distance apart, moving toward each other after they are released (that is, their initial velocities are zero right after they are released)?

Circle one: A B C D E F

(e 3pts) Which of the diagrams above corresponds to a system of two stars which start out far apart, moving toward each other (that is, their initial velocities are nonzero and they are heading straight at each other)?

Circle one: A B C D E F

(f 4pts) A comet is in an elliptical orbit around the Sun . Which of the diagrams above corresponds to the system described (the comet + the Sun)?

Circle one: A B C D E F

(g 4pts) A spacecraft leaves the Earth with an initial velocity that is just enough for it to escape from the Earth. Which of the diagrams above corresponds to the system described (the spacecraft + the Earth)?

Circle one: A B C D E F

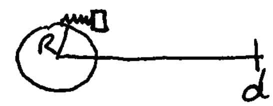
Problem 4 (25 Points)

A package of mass m sits on the surface of an airless asteroid of mass M and radius R. The package is launched by a large, powerful, low mass spring, whose stiffness is k_s. After launch, the package is observed to be moving at a speed of v_f when it is d from the center of the asteroid. Your answer to the following questions should be in terms of this given variables.

(a 15pts) Determine how much the launch spring was compressed.

Initial: $v_i = 0$; s; $-GMm/R$

Final: v_f; $s_f = 0$; $-GMm/d$



$$\Delta K + \Delta U_g + \Delta U_s = 0$$

$$\frac{1}{2}m(v_f^2 - \cancel{v_i^2}) + -GMm\left(\frac{1}{d} - \frac{1}{R}\right) + \frac{1}{2}k(\cancel{s_f^2} - s_i^2) = 0$$

$$\frac{1}{2}mv_f^2 - GMm\left(\frac{1}{d} - \frac{1}{R}\right) - \frac{1}{2}ks^2 = 0$$

$$\boxed{s = \sqrt{\frac{m}{k}v_f^2 - \frac{2GMm}{k}\left(\frac{1}{d} - \frac{1}{R}\right)}}$$

[−1.0
−2.0
−4.5
−12.0]

(b 10pts) Determine the minimum velocity of the package, when it is a distance d from the asteroid, such that the package will eventually escape the asteroid.

Initial: $v_i = v_{min}$; $r_i = d$

Final: $v_f = 0$; $r_f \to \infty$

[−0.5
−1.5
−3.0
−8.0]

$$\Delta K + \Delta U = 0$$

$$\frac{1}{2}m(\cancel{v_f^2} - v_i^2) + \left(\cancel{\frac{-GMm}{r_f}} - -\frac{GMm}{r_i}\right) = 0$$

$$-\frac{1}{2}mv_{min}^2 + \frac{GMm}{d} = 0$$

$$\frac{GM\cancel{m}}{d} = \frac{1}{2}\cancel{m}v_{min}^2 \Longrightarrow \boxed{v_{min} = \sqrt{\frac{2GM}{d}}}$$

This page is for extra work, if needed.

Things you must have memorized

The Momentum Principle Definition of Momentum	The Energy Principle Definition of Velocity	The Angular Momentum Principle Definition of Angular Momentum
Definitions of angular velocity, particle energy, kinetic energy, and work		

Other potentially useful relationships and quantities

$$\gamma \equiv \frac{1}{\sqrt{1-\left(\frac{|\vec{v}|}{c}\right)^2}} \qquad E^2 - (pc)^2 = \left(mc^2\right)^2$$

$$\frac{d\vec{p}}{dt} = \frac{d|\vec{p}|}{dt}\hat{p} + |\vec{p}|\frac{d\hat{p}}{dt} \qquad \vec{F}_{\parallel} = \frac{d|\vec{p}|}{dt}\hat{p} \text{ and } \vec{F}_{\perp} = |\vec{p}|\frac{d\hat{p}}{dt} = |\vec{p}|\frac{|\vec{v}|}{R}\hat{n}$$

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

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

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

$$\left|\vec{F}_{spring}\right| = k_s s \qquad U_{spring} = \frac{1}{2}k_s s^2$$

$$U_i \approx \frac{1}{2}k_{si}s^2 - E_M \qquad \Delta E_{thermal} = mC\Delta T$$

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots}{m_1 + m_2 + \ldots} \qquad I = m_1 r_{1\perp}^2 + m_2 r_{2\perp}^2 + \ldots$$

$$K_{tot} = K_{trans} + K_{rel} \qquad K_{rel} = K_{rot} + K_{vib}$$

$$K_{rot} = \frac{L_{rot}^2}{2I} \qquad K_{rot} == \frac{1}{2}I\omega^2$$

$$\vec{L}_A = \vec{L}_{trans,A} + \vec{L}_{rot} \qquad \vec{L}_{rot} = I\vec{\omega}$$

$$\omega = \sqrt{\frac{k_s}{m}} \qquad v = d\sqrt{\frac{k_{si}}{m_a}}$$

$$Y = \frac{F/A}{\Delta L/L} \text{ (macro)} \qquad Y = \frac{k_{si}}{d} \text{ (micro)}$$

$$\Omega = \frac{(q+N-1)!}{q!\,(N-1)!} \qquad S \equiv k\ln\Omega$$

$$\frac{1}{T} \equiv \frac{\partial S}{\partial E} \qquad \Delta S = \frac{Q}{T} \text{ (small } Q\text{)}$$

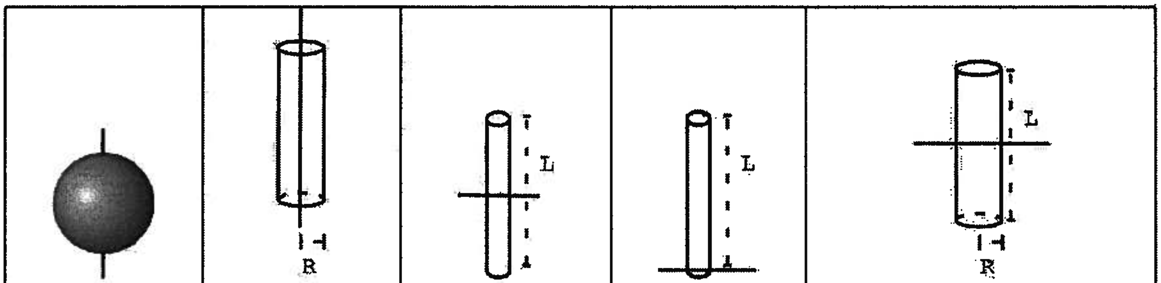
$$\text{prob}(E) \propto \Omega(E)\, e^{-\frac{E}{kT}} \qquad E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1,2,3\ldots$$

$$E_N = N\hbar\omega_0 + E_0 \text{ where } N = 0,1,2\ldots \text{ and } \omega_0 = \sqrt{\frac{k_{si}}{m_a}} \text{ (Quantized oscillator energy levels)}$$

Moment of intertia for rotation about indicated axis

The cross product

$$\vec{A} \times \vec{B} = \langle A_y B_z - A_z B_y, A_z B_x - A_x B_z, A_x B_y - A_y B_x \rangle$$



$I = \frac{2}{5} M R^2$	$I = \frac{1}{2} M R^2$	$I = \frac{1}{12} M L^2$	$I = \frac{1}{3} M L^2$	$I = \frac{1}{12} M L^2 + \frac{1}{4} M R^2$

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
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} atoms/mol
Plank's constant	h	6.6×10^{-34} joule $\cdot$ second
hbar $= \frac{h}{2\pi}$	$\hbar$	1.05×10^{-34} joule $\cdot$ second
specific heat capacity of water	C	4.2 J/g/K
Boltzmann constant	k	1.38×10^{-23} J/K

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}