Please remove this sheet before starting your exam.

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

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

$$E^2 - (pc)^2 = \left(mc^2\right)^2$$

$$\frac{d\vec{p}}{dt} = \frac{d|\vec{p}|}{dt}\hat{p} + |\vec{p}|\frac{d\hat{p}}{dt}$$

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

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

$$U_{grav} = -G\frac{m_1 m_2}{|\vec{r}|}$$

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

$$\Delta U_{grav} \approx mg\Delta y \text{ near Earth's surface}$$

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

$$U_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|}$$

$$\left|\vec{F}_{spring}\right| = k_s s$$

$$U_{spring} = \frac{1}{2}k_s s^2$$

$$U_i \approx \frac{1}{2}k_{si}s^2 - E_M$$

$$\Delta E_{thermal} = mC\Delta T$$

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots}{m_1 + m_2 + \ldots}$$

$$I = m_1 r_{1\perp}^2 + m_2 r_{2\perp}^2 + \ldots$$

$$K_{tot} = K_{trans} + K_{rel}$$

$$K_{rel} = K_{rot} + K_{vib}$$

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

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

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

$$\vec{L}_{rot} = I\vec{\omega}$$

$$\omega = \sqrt{\frac{k_s}{m}}$$

$$v = d\sqrt{\frac{k_{si}}{m_a}}$$

$$Y = \frac{F/A}{\Delta L/L} \text{ (macro)}$$

$$Y = \frac{k_{si}}{d} \text{ (micro)}$$

$$\Omega = \frac{(q+N-1)!}{q!\,(N-1)!}$$

$$S \equiv k\ln\Omega$$

$$\text{prob}(E) \propto \Omega(E)\,e^{-\frac{E}{kT}}$$

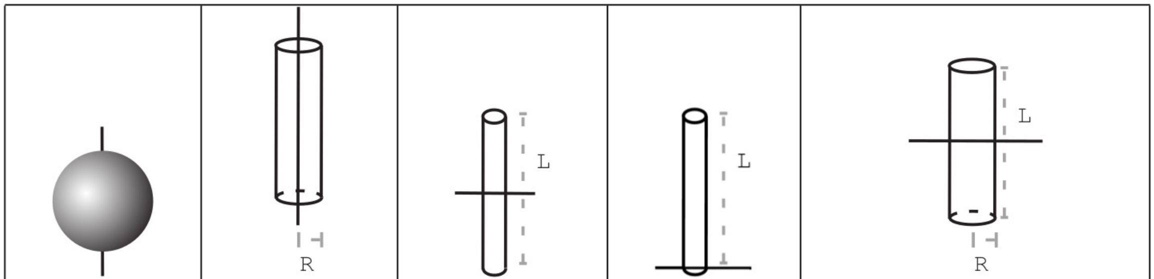
$$E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1,2,3\ldots$$

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

Moment of inertia for rotation about indicated axis

The cross product

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



$I = \frac{2}{5}MR^2$	$I = \frac{1}{2}MR^2$	$I = \frac{1}{12}ML^2$	$I = \frac{1}{3}ML^2$	$I = \frac{1}{12}ML^2 + \frac{1}{4}MR^2$

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}

PHYS 2211 Test 2 - Spring 2019

Please circle your lab section and then clearly print your name & GTID

Sections (M) 10AM, (K) 11AM		
Day	12-3pm	3-6pm
Monday	M01 K01	M02 K02
Tuesday	M03 K03	M04 K04
Wednesday	M05 K05	M06 K06
Thursday	M07 K07	M08 K08

Name: ______________________________

GTID: ______________________________

Instructions

- Please write with a pen or dark pencil to aid in electronic scanning.
- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- Your solution should be worked out algebraically. Numerical solutions should only be evaluated at the last step. Incorrect solutions that are not solved algebraically will receive an 80 percent deduction.
- 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 numeric results. Your symbolic answers should not have units.

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.

**"In accordance with the Georgia Tech Honor Code,
I have not given or received unauthorized aid on this test."**

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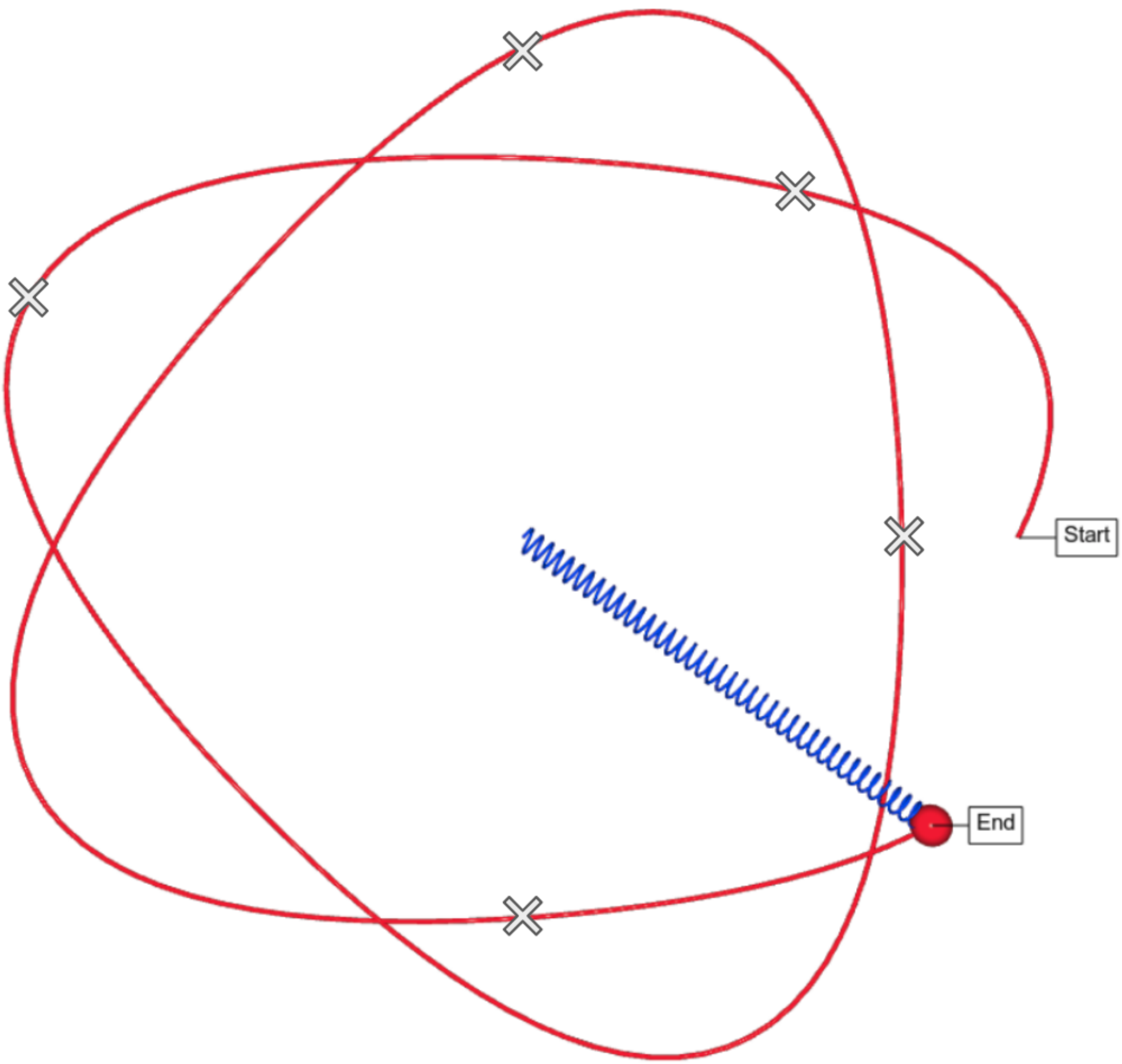
Sign your name on the line above

Problem 1 [25 pts]

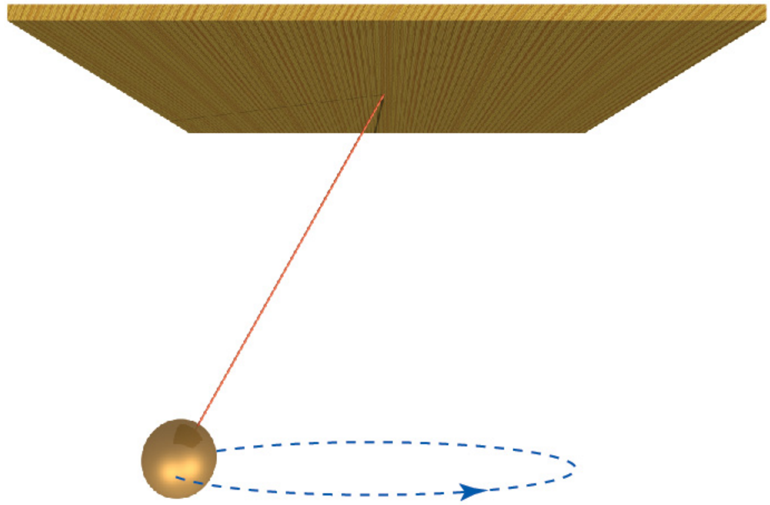
A mass and an ideal spring are laying on top of a table with one end of the spring fixed at the center of the table. The spring is stretched and the mass is given an initial velocity so that it moves around on the table as indicated in the diagram. Along the trajectory are five points marked with an "X". At each of these points draw an arrow to indicated the following at that particular instant in time. Please pay careful attention to the length of your arrows.

- $\hat{p}$
- $\vec{F}_{spring}$
- $\vec{F}_{spring,\parallel}$
- $\vec{F}_{spring,\perp}$
- Indicate if the object is: speeding up, slowing down or constant



Problem 2 [25 pts]

A ball of mass m is suspended from a string, and after being given a push, moves along a horizontal circular path like the one shown in the diagram. The length of the string is L and the angle the string makes with the vertical axis is a constant θ. As you watch the ball travel around it's circular path you notice that the ball is traveling with an unknown constant speed. The only forces acting on the ball are the forces of the string and the Earth.



A. [5 pts] Calculate the parallel component of the rate of change of momentum for the ball.

B. [5 pts] Calculate the perpendicular component of the rate of change of momentum for the ball.

C. [5 pts] Determine the magnitude of the tension in the string.

D. [10 pts] Calculate the speed of the ball in terms of the known quantities given in the problem statement and universal constants.

Problem 3 [25 pts]

A proton of mass 1.6726×10^{-27} kg is emitted by a supernova with a speed of $0.9c$, where $c = 3 \times 10^{8}$ m/s is the speed of light.

A. [5 pts] Calculate the kinetic energy of the proton.

B. [10 pts] A force of $\langle 2 \times 10^{-8}, -4 \times 10^{-8}, 3 \times 10^{-8} \rangle$ N acts on the proton as it moves over a displacement of $\langle -0.03, 0.05, 0.07 \rangle$ m. Calculate the work done on the proton by this force?

C. [10 pts] After the work was done to the proton, it collides with a stationary neutron that has a mass 1.6749×10^{-27} kg to form a new particle called a deuteron. In this process, a gamma ray (high-energy photon) is emitted, and its energy is measured to be 3.5248×10^{-13} J. Keeping all five significant figures, what is the mass of the deuteron? You can assume that deuteron is stationary.

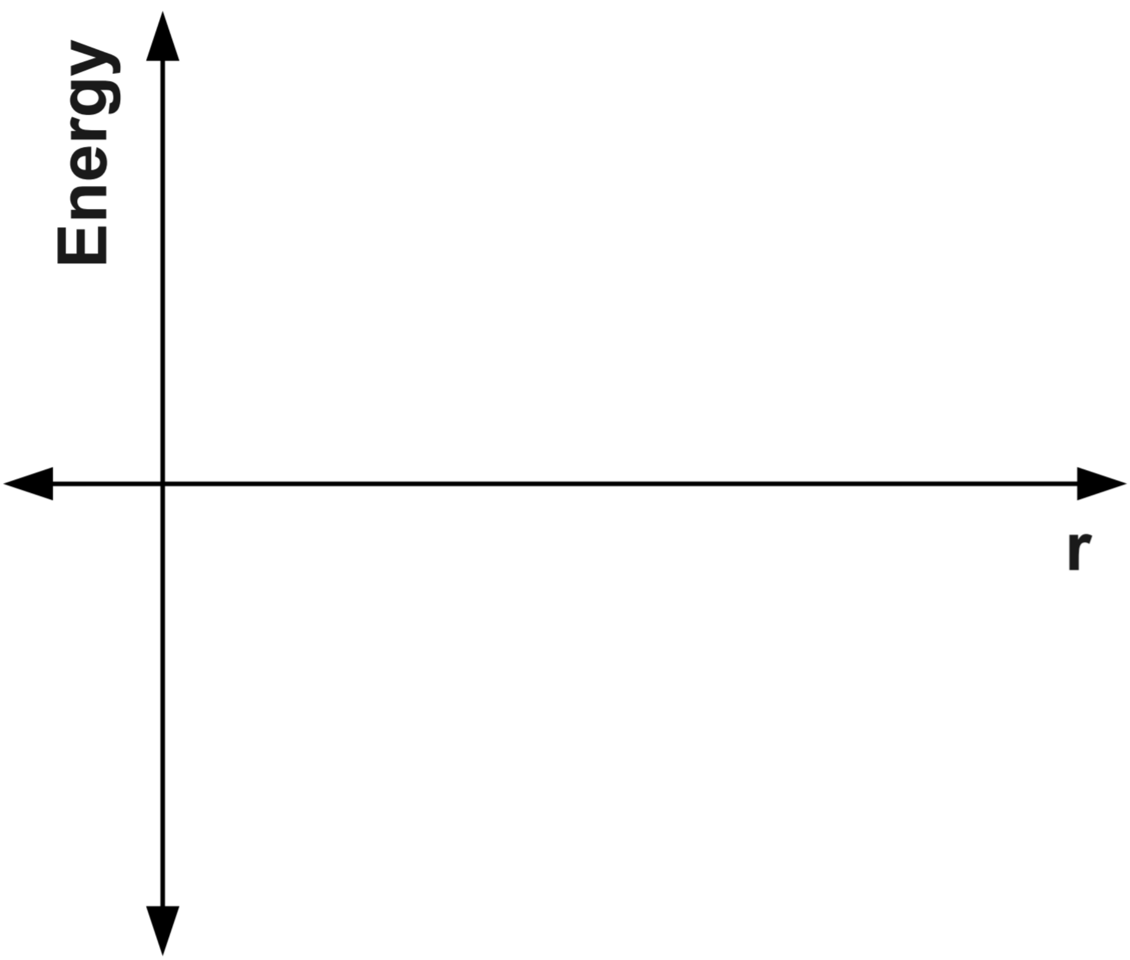
`Problem 4 [25 pts]`

A robot spacecraft lands on an asteroid, picks up a sample, and blasts off to return to Earth. When it is 200 km from the center of the asteroid, its speed is 5.0 m/s, and the rockets are turned off. At the moment when it has coasted to a distance 500 km from the center of the asteroid, its speed has decreased to 4.1 m/s. In the following questions you can assume that the asteroid is massive enough (compared to the spacecraft) that its kinetic energy change is negligible.

A. [10 pts] Calculate the mass of the asteroid.

B. [10 pts] Calculate the velocity of the space craft when it is very far away from the asteroid (i.e. $r \to \infty$).

C. [5 pts] On the diagram below, draw a graph of the gravitational potential energy U as a function of separation distance r between the spacecraft and the asteroid. Next, draw the total energy $(K + U)$ for the asteroid and spacecraft. Finally, draw the kinetic energy K as a function of separation distance.



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