PHYS 2211 Test 2
Fall 2015

Name(print)_____ Section # _____

Fenton (C), Gumbart (M), Schatz(N)			
Day	12-3pm	3-6pm	6-9pm
Monday	C02 N02	C01 M01	
Tuesday	M03 N01	M06 C03	C04 N03
Wednesday	C05 N05	M02 N06	
Thursday	M04 C06	M05 N04	

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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8 \times 10^{-3})(5 \times 10^{6})}{(2 \times 10^{-5})(4 \times 10^{4})} = 5 \times 10^{4}$

- Give standard SI units with your numeric 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.

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

Problem 1 (25 Points)

Below is an incomplete program to predict the motion of a white particle. The net force on the white particle is exerted by a red particle; the force acts along the line joining the two particles and is attractive. The magnitude of the force is given by $k|\vec{r}|^7$, where k is a positive constant and $\vec{r}$ is the position vector pointing from the red particle to the white particle.

Write the necessary statements to complete the code to predict the white particle's motion. Assume the white particle starts from rest and the red particle is motionless.

```
GlowScript 1.1 VPython

# Objects
redParticle = sphere(pos=vector(5,4,0), radius=0.25, color=color.red)
whiteParticle = sphere(pos=vector(-3,-2,0), radius=0.25, color=color.white)
# Constants
k = 0.3
redParticle.m = 10
whiteParticle.m = 5e-3

#(a 5pts) Add the initializations required for the while loop below




t = 0
deltat = 5e-6
while t < 1:
    #(b 20pts) update the force, momentum, and position for the white particle




    t = t + deltat
```
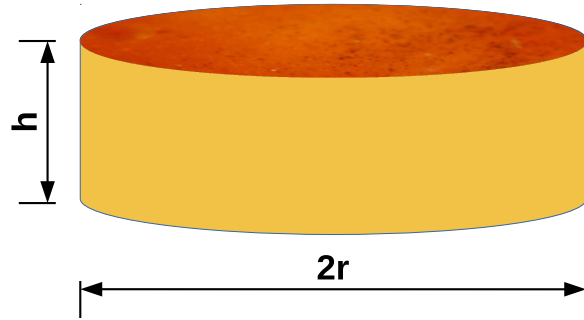
Problem 2 (25 Points)

You are making flan for Prof. Fenton's birthday and want to add fruit to the top but are worried about crushing and ruining your dessert. The flan is a cylinder with a radius of $r = 0.13$ m, a height of $h = 0.10$ m, and a mass of 6.86 kg.

(a 5pts) Calculate the density of flan.

(b 5pts) When you slap the top of the flan, it oscillates up and down with a frequency of 2 Hz (recall $\omega = 2\pi f$). Determine the macroscopic stiffness k_s of the flan. Hint: think of the flan as one big spring with a mass of 6.86 kg attached to the end.

(c 5pts) A fruit topping is placed on the flan which compresses by 0.01 m. Calculate the mass of the fruit topping.

(d 5pts) Calculate the Young's modulus for flan.

(e 5pts) Prof. Schatz takes a slice that is one quarter of the flan (same height but 1/4 the area). How much does his flan compress if he piles half of the fruit, from the whole flan, on top of his single piece?

(extra credit 5pts) Before piling fruit onto his piece of flan, Prof Schatz's slaps the top of his flan and watches it oscillate up and down. Calculate the frequency of this oscillation in Hertz.

Problem 3 (25 Points)

A block of mass m is suspended motionless by a string and three identical springs as shown in the figure. Each spring has stiffness k and relaxed length L_0. The spring from above forms an angle θ with the horizontal, the string has an unknown tension and the Earth's gravity points down. Recall that the force for an ideal spring is given by $\vec{F} = -k(|\vec{L}| - L_0)\hat{L}$ where $\vec{L}$ points from the attachment point to the block.
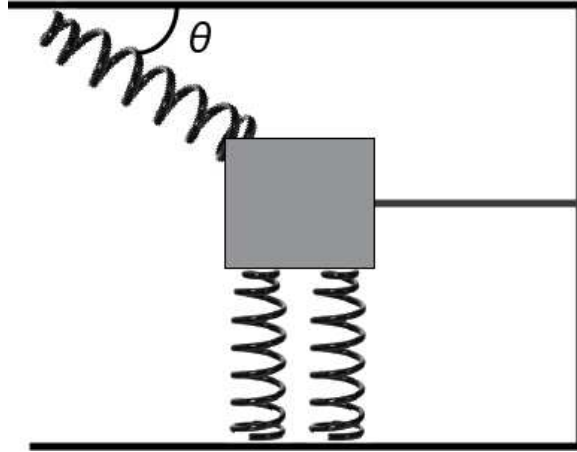

(a 10pts) Determine the tension T in the string if the stretched length of the upper spring is $3L_0$. It will help if you start by identifying the forces acting on the system and sketch a corresponding force diagram.

(b 5pts) If you treat the two lower springs as a single spring, what is the effective spring constant k_{eff}?

(c 10pts) Calculate their length in the current state and indicate if they are extended or compressed. **(Pay careful attention to directions!)**

Two blocks of mass m_1 and m_2 are pulled over a hill by an external force $\vec{F}$ as shown in the diagram. The coefficient of friction between the two blocks is μ and the center of the top block moves through a radius of curvature R. At the top of the hill, the top block slips (slides on the bottom block). At that instant, with respect to the hill, the top block is moving to the right with speed v.
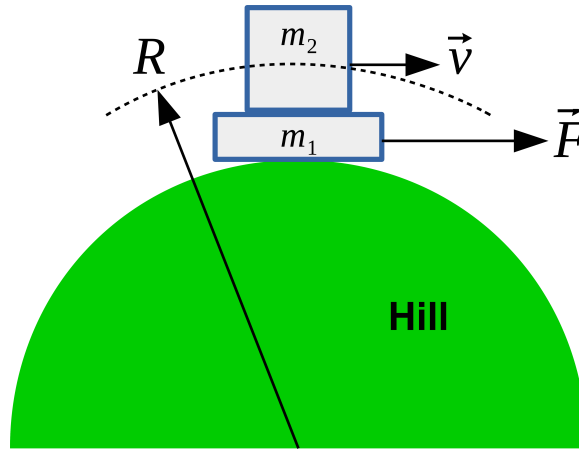
(a 4pts) Determine the magnitude and direction of $(\dfrac{d\vec{p}}{dt})_\perp$ for the top block at the instant the block is at the top of the hill.

(b 5pts) Identify the forces acting on the top block and sketch a corresponding force diagram.

(c 10pts) Determine the magnitude and direction of the perpendicular component of the force the bottom block exerts on the top block. **Warning $(\vec{F}_{net})_\perp \neq 0$)!**

(d 6pts) Determine the magnitude and direction of the parallel component of the force the bottom block exerts on the top block.

This page is for extra work, if needed.

Things you must have memorized

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

Other potentially useful relationships and quantities

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{1}{T} \equiv \frac{\partial S}{\partial E}$$

$$\Delta S = \frac{Q}{T} \text{ (small } Q\text{)}$$

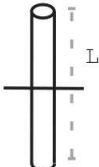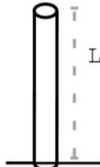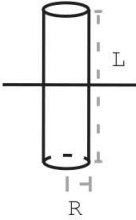$$\text{prob}(E) \propto \Omega\left(E\right) e^{-\frac{E}{kT}}$$

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

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

Moment of intertia for rotation about indicated axis

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

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

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	$\dfrac{1}{4\pi\epsilon_0}$	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 $= \dfrac{h}{2\pi}$	$\hbar$	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}