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

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

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

$$\vec{F}_{grav}=-G\frac{m_1m_2}{|\vec{r}|^2}\hat{r} \qquad U_{grav}=-G\frac{m_1m_2}{|\vec{r}|}$$

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

$$\vec{F}_{elec}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{|\vec{r}|^2}\hat{r} \qquad U_{elec}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{|\vec{r}|}$$

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

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

$$\vec{r}_{cm}=\frac{m_1\vec{r}_1+m_2\vec{r}_2+\dots}{m_1+m_2+\dots} \qquad I=m_1r_{1\perp}^2+m_2r_{2\perp}^2+\dots$$

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

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

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

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

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

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

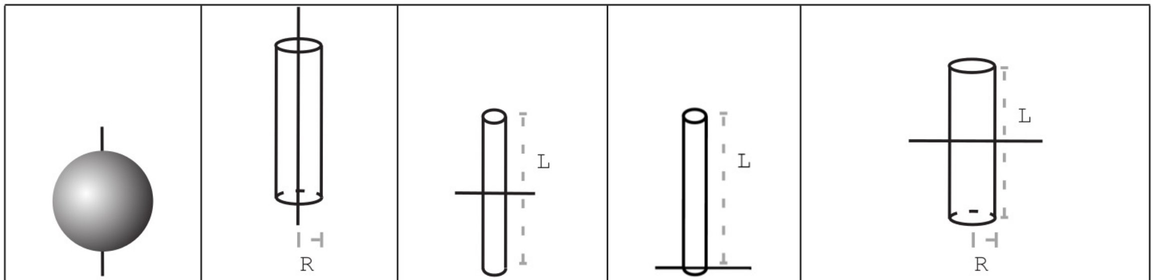
$$\text{prob}(E)\propto\Omega(E)\,e^{-\frac{E}{kT}} \qquad E_N=-\frac{13.6\text{eV}}{N^2}\text{ where } N=1,2,3\dots$$

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

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 - Fall 2018

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

Sections (M) Parker, (N) Yunker		
Day	12-3pm	3-6pm
Monday	M01 N01	M02 N02
Tuesday	M03 N03	M04 N04
Wednesday	M05 N05	M06 N06
Thursday	M07	N07

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]

Below is a programming shell to model the interaction of two particles. The force acting on the white particle is directed along the line connecting the two particles and is attractive. Its magnitude is given by $|\vec{F}| = \dfrac{k}{|\vec{r}|^3}$, where $|\vec{r}|$ is the separation between the particles and k is a positive constant. There are no other forces acting on the particles.

Write the necessary statements to compute the force on the white particle and update its momentum. The red particle will remain still.

```
GlowScript 2.7 VPython

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)
k = 0.3 # Nm^3
redParticle.m = 1 # kg
whiteParticle.m = 5e-3 # kg
whiteParticle.p = whiteParticle.m*vector(800,800,0)
t = 0 # seconds
deltat = 5e-6 # seconds
while t < 1:
     ## A. [10pts] Compute the net force on the white particle









     ## B. [10pts] Update the momentum of the white particle





     ## C. [5pts] Update the position of the white particle





    ## Increase time
    t = t + deltat
```

Problem 2 [25 pts]

Two UFOs are floating through space, far from any planet. UFO_1 has mass 8500 kg, and initial velocity $< 15, 0, 0 >$ m/s. UFO_2 also has mass 8500 kg, and initial velocity $< 0, 0, 0 >$ m/s. The UFOs collide!

A. [3 pts] What is the total momentum before they collide?

$\vec{p} =< \quad , \quad , \quad > \text{kg}\frac{\text{m}}{\text{s}}$

B. [3 pts] What is the total momentum after they collide?

$\vec{p} =< \quad , \quad , \quad > \text{kg}\frac{\text{m}}{\text{s}}$

C. [4 pts] If the velocity of UFO_1 after the collision is $< 0, 0, 0 >$ m/s, what is the momentum of UFO_2?

$\vec{p} =< \quad , \quad , \quad > \text{kg}\frac{\text{m}}{\text{s}}$

D. [3 pts] What is the velocity of UFO_2 after the collision?

$$\vec{v} =< \quad , \quad , \quad > \frac{\text{m}}{\text{s}}$$

E. [5 pts] If the collision took 0.2 seconds, what was the average net force on UFO_1?

$$\vec{F} =< \quad , \quad , \quad > \text{N}$$

F. [3 pts] Two new UFOs collide, far from any planet. UFO_3 has mass 8500 kg, and initial velocity $< 15, 0, 0 >$ m/s. UFO_4 also has mass 8500 kg, and initial velocity $< 0, 0, 0 >$ m/s. After their collision, the UFOs stick together. What is the momentum of the UFOs after the collision?

$$\vec{p} =< \quad , \quad , \quad > \text{kg}\frac{\text{m}}{\text{s}}$$

G. [4 pts] What is the speed of UFO_3 after the collision?

$$|\vec{v}| = \quad \frac{\text{m}}{\text{s}}$$

`Problem 3 [25 pts]`

Prof. Yunker has a pile of scrambled eggs. When you look closer, you realize he isn't eating them, but measuring their physical properties. The eggs have been shaped into a disc with a height of 0.2 m and a radius of 0.1 m. Prof. Yunker compresses the eggs with a force of 0.5 N, and measures the new height of the eggs to be 0.17 m. During this experiment the effect of gravity on the eggs can be ignored.

A. [7 pts] Determine the spring constant of the egg disc.

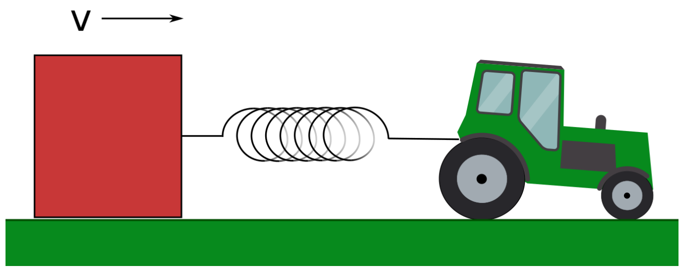
B. [8 pts] Calculate the Young's modulus of the egg disc.

C. [2 pts] Prof. Yunker cuts the egg disc in half, so it now has a height of 0.1 m. What is the Young's modulus for the new egg disc?

D. [8 pts] The eggs are made from proteins that are 4 nm in diameter. What is the stiffness of these proteins?

Problem 4 [25 pts]

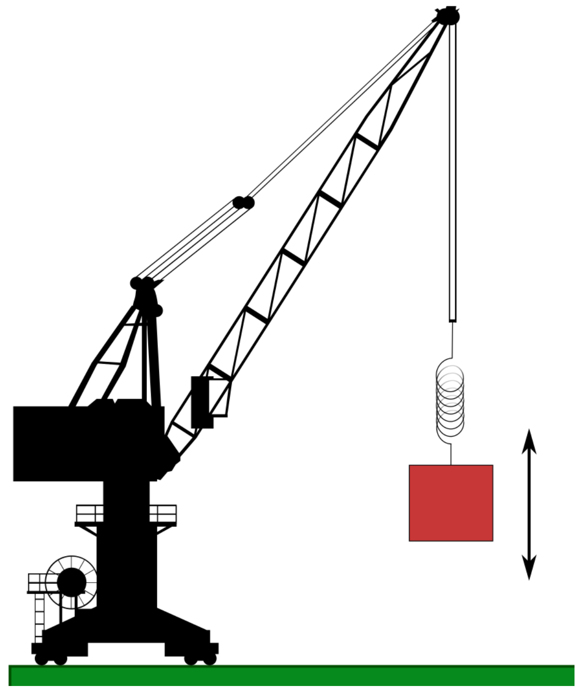
A block of mass $m = 1000$ kg is being pulled across a surface, connected to a tractor by a spring of stiffness $k = 4900$ N/m and relaxed length $L_0 = 4$ m. The whole assemblage moves with constant speed $v = 3$ m/s. The coefficient of sliding friction between the block and the ground is $\mu_k = 0.5$, while the coefficient of static friction is $\mu_s = 0.75$.



A. [8 pts] Draw a force body diagram and label all of the forces acting on the block. The relative length of your arrows should scale with the forces so that if one force is twice as large as another it's arrow will be twice as long.

B. [10 pts] Calculate the length, L, of the spring as the block slides along the ground.

C. [7 pts] Suppose the block is detached from the tractor and lifted by a crane *using the same spring*. As the block bobs up and down, determine the period of oscillation.



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