PHYS 2211 Test 1
Spring 2014

Name(print) Test Key ~ Test Key ~ Test Key ~ Lab Section $\boxed{\text{KEY}}$

Greco(K)			
Day	12-3pm	3-6pm	6-9pm
Monday		K01 K02	
Wednesday	K03 K05	K04 K07	K06 K08

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."

Zaphod Beeblebrox

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)

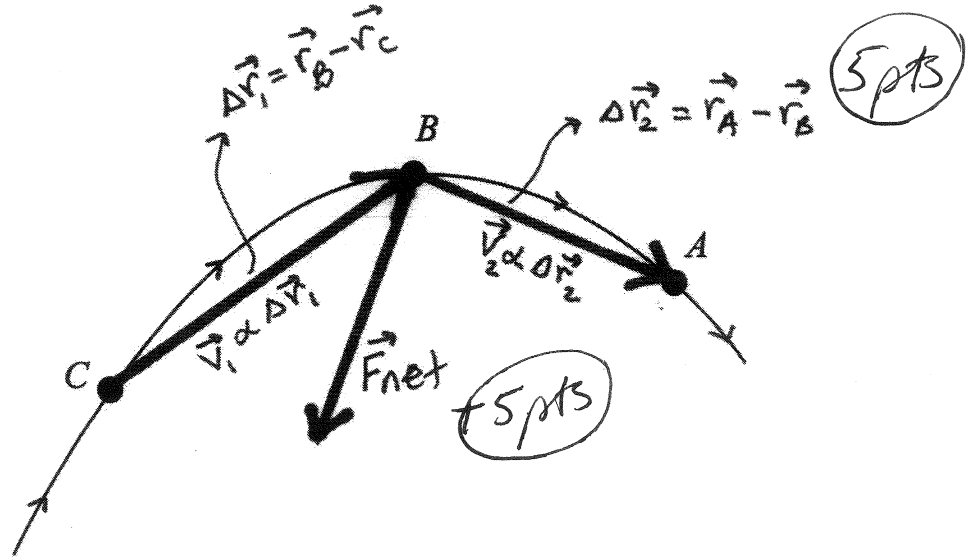
(a 5pts) Write down any **one** of the valid forms of the momentum principle. If you write more than one and any of them are incorrect, the whole problem will be marked as incorrect. Your answer must be exactly correct to receive credit, including arrows for vectors, correct subscripts, etc. There is no partial credit for this part.

$\frac{d\vec{p}}{dt} = \vec{F}_{net}$ (or) $\Delta\vec{p} = \vec{F}_{net}\Delta t$ (or) $\vec{p}_f = \vec{p}_i + \vec{F}_{net}\Delta t$

(etc)

All

As an object moves along a curve, a camera takes three pictures of the object. The time between pictures is one second. The locations of the object in the pictures are labeled A, B, and C as the object moves from left to right on the diagram.



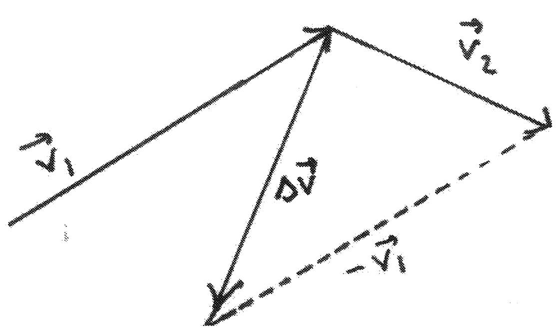
(b 10ts) On the diagram, draw the average velocity at locations A and B. +5 for everyone

(c 5pts) On the diagram, draw a vector representing the net force on the object at location B.

(d 5pts) In your own words, explain how you determined the direction of the net force acting on the object at location B.

$\Delta\vec{r} = \vec{v}_{Avg}\Delta t$ → since Δt is a positive scalar, then $\vec{v}_{Avg}$ points in the same direction as $\Delta\vec{r}$

$\vec{F}_{net} = \frac{m\Delta\vec{v}}{\Delta t}$ → since m and Δt are positive scalars, then $\vec{F}_{net}$ points in the same direction as $\Delta\vec{v}$



$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1 = \vec{v}_2 + (-\vec{v}_1)$

All

Problem 2 (25 Points)

(a 5pts) Write down the definition of the momentum of a particle that is valid at all speeds. ***Your answer must be exactly correct to receive credit, including vectors, correct subscripts, etc.*** There is no partial credit.

$\vec{p} = \gamma m \vec{v}$, where $\gamma = \dfrac{1}{\sqrt{1 - v^2/c^2}}$

All

−0.5
−1.5
−3.0
−8.0

(b 10pts) A positron is moving at a speed comparable to that of light. It has a momentum of 7×10^{-22} kg $\cdot \frac{\text{m}}{\text{s}}$. What is the speed of the positron? Express your answer as a fraction of the speed of light.

(B)

(C)

$p = \gamma m v = 7e{-22}$

$\gamma v = (7e{-22})/(9e{-31})$

$\gamma v = 7.78e8$

$\dfrac{v}{\sqrt{1 - v^2/c^2}} = 7.78e8$

$\dfrac{v^2}{1 - v^2/c^2} = 6.05e17$

$v^2 = 6.05e17(1 - v^2/c^2)$

$v^2 = 6.05e17 - 6.05e17(v^2/c^2)$

$v^2c^2 = 6.05e17c^2 - 6.05e17v^2$

$\rightarrow v^2c^2 + 6.05e17v^2 = 6.05e17c^2$

$v^2(c^2 + 6.05e17) = 6.05e17c^2$

$v^2 = \dfrac{6.05e17\,c^2}{c^2 + 6.05e17}$

$v^2 = \dfrac{(6.05e17)(3e8)^2}{(3e8)^2 + 6.05e17} = \dfrac{5.445e34}{6.95e17}$

$v^2 = 7.835e16 \Rightarrow v = 2.799e8 \text{ m/s}$

$v = \dfrac{2.799e8}{3e8} \Rightarrow \boxed{v = 0.933c}$

(c 10pts) A muon is a subatomic particle with a mass of 1.9×10^{-28} kg. A muon in a particle accelerator initially has velocity of $\langle 0.80c, 0.50c, 0 \rangle$, where c is the speed of light. A short time later, the muon has a velocity of $\langle 0.80c, -0.50c, 0 \rangle$. Calculate the unit vector that points in the same direction as the change in momentum of the muon over this short time interval?

$\left.\begin{array}{l} \vec{v}_i = \langle 0.8c, 0.5c, 0 \rangle \\ \vec{v}_f = \langle 0.8c, -0.5c, 0 \rangle \end{array}\right\}$ $\Delta\vec{v} = \vec{v}_f - \vec{v}_i = \langle 0.8c, -0.5c, 0 \rangle - \langle 0.8c, 0.5c, 0 \rangle$

$= \langle 0, -c, 0 \rangle$

$|\Delta\vec{v}| = \sqrt{(-c)^2} = c$

$\hat{\Delta v} = \dfrac{\Delta\vec{v}}{|\Delta\vec{v}|} = \dfrac{\langle 0, -c, 0 \rangle}{c} = \boxed{\langle 0, -1, 0 \rangle}$

* Since $\Delta\vec{p} = m\Delta\vec{v}$, and m is a positive scalar, then $\Delta\vec{p}$ and $\Delta\vec{v}$ point in the same direction $\Rightarrow$ they have the same unit vector

Problem 3 (25 Points)

A falling rubber ball bounces off the floor. The velocity just before it hits the floor is $\langle 1.9, -6.2, 0\rangle$ m/s. Just after it hits the floor, the ball's velocity is $\langle 1.9, 5.2, 0\rangle$ m/s. The ball's mass is 0.046 kg. The ball is in contact with the floor for only 1.7×10^{-3} seconds.

(a 10pts) During the bounce, the ball was deformed (crushed) by a small amount d. Calculate the approximate size of this deformation.

$$V_{Avg,y} = \frac{V_{i,y} + V_{f,y}}{2} = \frac{-6.2+0}{2} = -3.1 \text{ m/s}$$

* Only counting y-direction because the deformation only happens in that direction
* At maximum deformation, $V = 0$.

$d = |\Delta r| = |V_{Avg}\,\Delta t| \rightarrow$ only in y-direction

$= \left|(-3.1)\left(\frac{1.7e-3}{2}\right)\right| \rightarrow$ because the deformation happens when the ball comes in, during half the total time in contact

$= |(-3.1)(8.5e-4)| = |-2.635e-3| =$

$$\boxed{d = 2.635e-3 \text{ m}}$$

−0.5
−1.5
−3.0
−8.0

(b 15pts) What is the net force exerted on the ball during the time it is in contact with the floor? (You may assume the net force is approximately constant.) Express your result as a vector.

$$\Delta\vec{V} = \frac{\vec{F}_{net}}{m}\Delta t$$

$\Delta V_y = \frac{F_{net,y}}{m}\Delta t \rightarrow$ again, only y-component because that is the direction of the deformation

$$F_{net,y} = \left(\frac{m}{\Delta t}\right)(V_{f,y} - V_{i,y}) =$$

$$= \left(\frac{0.046}{1.7e-3}\right)(5.2 - -6.2) = (27.059)(11.4) =$$

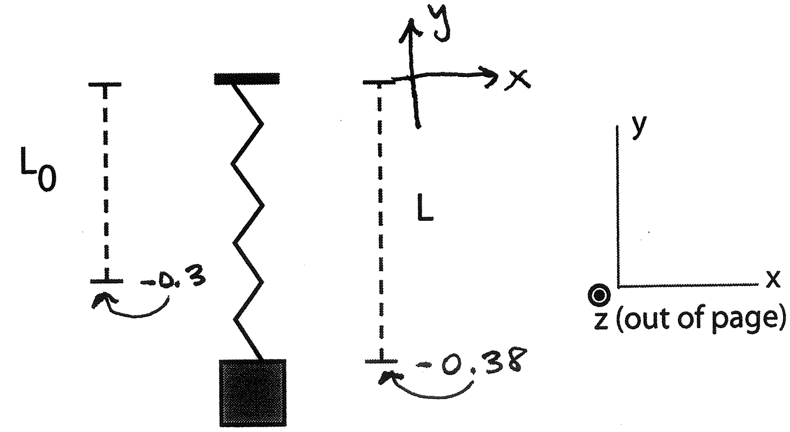
−1.0
−2.0
−4.5
−12

$$\boxed{F_{net,y} = 308.47 \text{ N}}$$

$$\boxed{\vec{F}_{net} = \langle 0, 308.47, 0\rangle \text{ N}}$$

Problem 4 (25 Points)

A block with a mass of 0.035 kg is oscillating vertically on a spring with a spring stiffness of 15 N/m and a relaxed length $L_0 = 0.30$ m. At the instant shown in the diagram, the spring's length is $L = 0.38$ m, and the block is moving downward at a speed of 1.9 m/s.



(a 5pts) What is the net force acting on the block? ***Express your answer as a three-component vector.***

$$\vec{F}_{net} = \vec{F}_{spring} + \vec{F}_{Earth} \Rightarrow \text{all in } y\text{-direction} \quad (2\text{pts})$$

$$= -k\Delta L + (-mg) = -k(L - L_0) - mg =$$

$$= (-15)(-0.38 - -0.30) - (0.035)(9.81) = \quad (2\text{pts})$$

$$= 1.2 - 0.34335 = 0.85665 \text{ N}$$

$$\boxed{\vec{F}_{net} = \langle 0, 0.85665, 0 \rangle \text{ N}} \quad (1\text{pt})$$

(b 5pts) At this instant, the speed of the block is (circle one): All

increasing $\boxed{\text{decreasing}}$ not changing (c 5pts) What is the new speed of the block 0.01 seconds after the instant shown in the diagram? ***Start from a fundamental principle and show all work.***

$$\vec{v}_f = \vec{v}_i + (\vec{F}_{net}/m)\,\Delta t = \quad (2\,pts)$$

$$= \langle 0, -1.9, 0\rangle + \left(\frac{0.01}{0.035}\right)\langle 0, 0.85665, 0\rangle = \quad (2\,pts)$$

$$= \langle 0, -1.9, 0\rangle + \langle 0, 0.2448, 0\rangle =$$

$$\boxed{\vec{v}_f = \langle 0, -1.6552, 0\rangle \text{ m/s}} \quad \text{(velocity)}$$

$$\boxed{v_f = 1.6552 \text{ m/s}} \quad \text{(speed)} \quad (1\,pt)$$

(d 10pts) How far does the block move during this 0.01 second interval? Be sure to show your work

✓ Assume Δt is small enough for force to be constant

✓ Use $\vec{v}_f$ as $\vec{v}_{Ave}$ (like what vpython does)

$$\Delta\vec{r} = \vec{v}\,\Delta t = \langle 0, -1.6552, 0\rangle (0.01) =$$

$$\boxed{\Delta\vec{r} = \langle 0, -0.016552, 0\rangle \text{ m}}$$

* The block moved 0.016552 meters downwards.

−0.5
−1.5
−3.0
−8.0

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

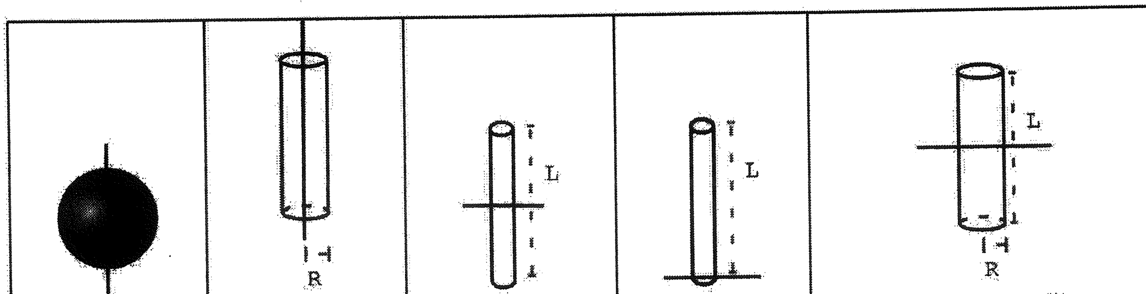
$$\text{prob}(E) \propto \Omega(E)\, e^{-\frac{E}{kT}} \qquad E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1, 2, 3\ldots$$

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

Moment of intertia for rotation about indicated axis

The cross product

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



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

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}