PHYS 2211 Test 1
Fall 2012

Name(print) Key **Lab Section** 

Lab section by day and time: Fenton (N), Greco(N)				
Day	12-3pm	1-4pm	3-6pm	4-7pm
Monday	M01 M02		N01 N02	
Tuesday		M03 N03		M04 N04
Wednesday	M05 N05		M06 N06	
Thursday		M07 N07		M08 N08

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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5\times10^{4}$
- 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."

Batman

Sign your name on the line above

PHYS 2211

Do not write on this page!

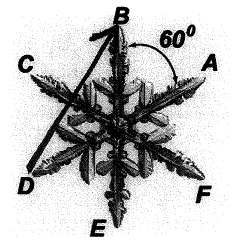
Problem	Score	Grader
Problem 1 (25 pts)		
Problem 2 (25 pts)		
Problem 3 (25 pts)		
Problem 4 (25 pts)		

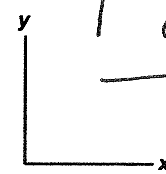
Problem 1 (25 Points)

$\boxed{-1 \text{ for units}}$

Snowflakes have six-fold symmetry with arms of identical length. In the example shown below, a snowflake oriented in the x-y plane, has tip A located at $\langle 4.33, 2.5, 0\rangle$ mm with respect to the center of the snowflake which is at $\langle 0, 0, 0\rangle$ mm.

Snowflake lies in the x-y plane





(1a 5pts) What is the distance of tip A from the center?

$$3\text{pts}\left\{\ \vec{r} = \vec{r}_{obs} - \vec{r}_{src} = \langle 4.33, 2.5, 0\rangle - \langle 0,0,0\rangle = \langle 4.33, 2.5, 0\rangle\right.$$

$$2\text{pts}\left\{\ |\vec{r}_A| = \sqrt{(4.33)^2 + (2.5)^2 + 0^2} = \sqrt{25} = \boxed{5\,\text{mm}}\right.$$

(1b 5pts) What is the position vector of tip D relative to the center of the snowflake?

$$\underbrace{\vec{r}_D = -\vec{r}_A}_{3\text{pts}} = -\langle 4.33, 2.5, 0\rangle\text{mm} = \underbrace{\langle -4.33, -2.5, 0\rangle\text{mm}}_{2\text{pts}}$$

(1c 5pts) What is the position vector of tip B relative to tip D? Draw this vector on the snowflake. (2pts)

$$2\text{pts}\left\{\ \vec{r}_{BD} = \vec{r}_B - \vec{r}_D \qquad \vec{r}_B = |\vec{r}_B|\,\hat{r}_B \qquad |\vec{r}_B| = |\vec{r}_A| = 5\,\text{mm} \qquad \hat{r}_B = \langle 0, 1, 0\rangle\right.$$

$$1\text{pts}\left\{\ \vec{r}_{BD} = \langle 0, 5, 0\rangle - \langle -4.33, -2.5, 0\rangle = \boxed{\langle 4.33, 7.5, 0\rangle\text{mm} = \vec{r}_{BD}}\right.$$

(1d 5pts) What is the magnitude of the vector you calculated in part (1c)?

$$|\vec{r}_{BD}| = \sqrt{(4.33)^2 + (7.5)^2 + 0^2} = \sqrt{75.0\,\text{mm}^2} = \boxed{8.66\,\text{mm}}$$

All or nothing

(1e 5pts) What is the unit vector pointing in the direction of the vector you calculated in part (1c)?

$$\underbrace{\hat{r}_{BD} = \frac{\vec{r}_{BD}}{|\vec{r}_{BD}|}}_{3\text{pts}} = \frac{\langle 4.33, 7.5, 0\rangle}{8.66} = \underbrace{\boxed{\langle 0.5, 0.866, 0\rangle = \hat{r}_{BD}}}_{2\text{pts}}$$

Problem 2 (25 Points)

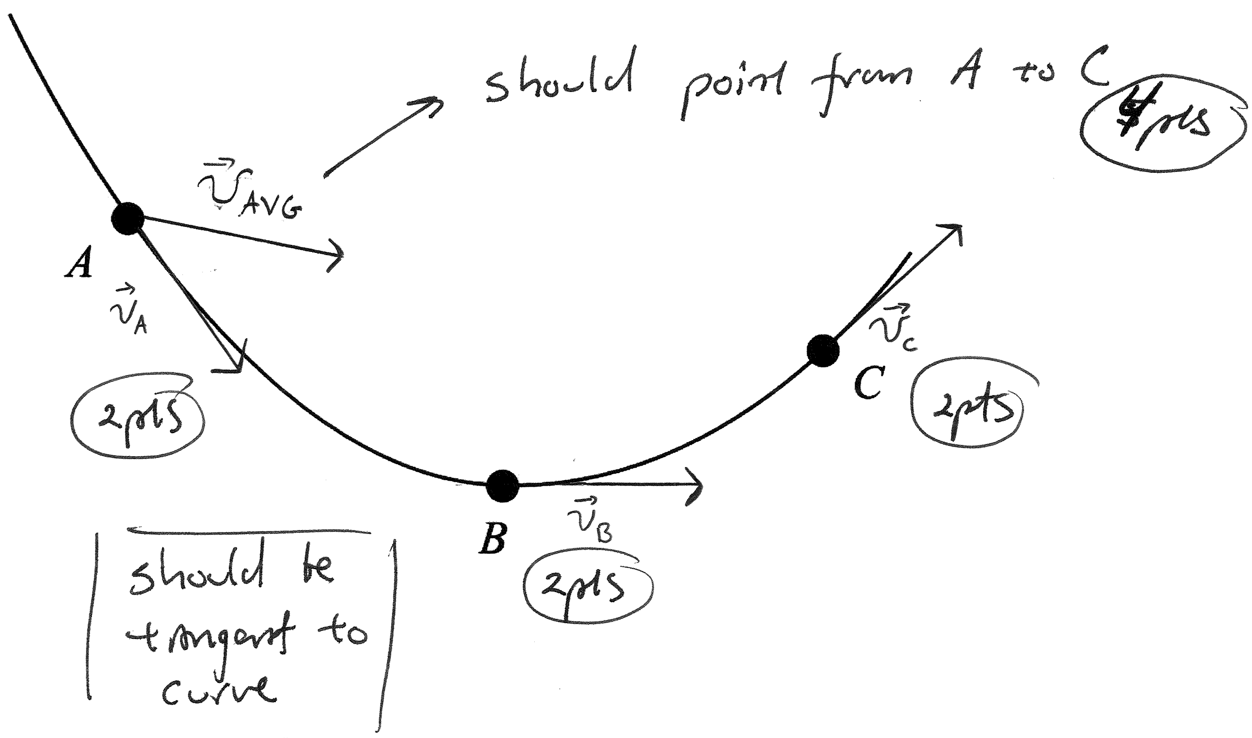
(a 5pts) Write down any **one** of the valid forms of the momentum principle. If you write more than one and any of them are incorrect, the whole problem will be marked as incorrect. Your answer must be exactly correct to receive credit, including arrows for vectors, correct subscripts, etc. There is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

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

All or nothing

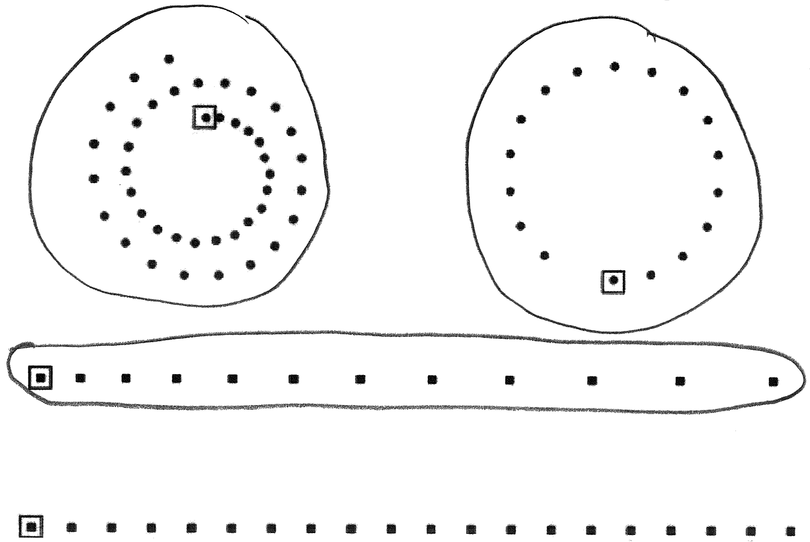
(b ~~5~~ 6pts) A car travels on a curving road from point A to B to C as shown in the diagram. On the diagram below, draw and label vectors with tails at points A, B, and C to represent the instantaneous directions of the velocities at those points.

(c ~~5~~ 4pts) On the diagram below, draw and label an arrow with its tail at location A to represent the direction of the average velocity of the car as it moves from A to C.



(d 5pts) Below are several snapshots of a particle taken at equal time intervals. Circle the trajectories that indicate an interaction is taking place between the particle and its surroundings.

All
or
Nothing



(e 5pts) An electron with a speed of 0.98c is emitted by a supernova, where c is the speed of light. The electron is then decelerated by a constant force for 0.25 seconds. After this time the speed of the electron is 0.91c. What is the magnitude of this force?

1pt
$$\Delta\vec{p} = \vec{F}_{net}\Delta t$$
$$\vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t} \Rightarrow |\vec{F}_{net}| = \left|\frac{\Delta\vec{p}}{\Delta t}\right|$$

2pts
$$\boxed{p_1 = \gamma_1 m v_1} = \frac{m v_1}{\sqrt{1-(\frac{v_1}{c})^2}} = \frac{m(0.98c)}{\sqrt{1-(0.98)^2}} = \frac{m(0.98c)}{\sqrt{1-0.96}} = \frac{m(0.98c)}{0.199}$$

$$p_1 = 4.9\,mc$$

$$p_2 = \gamma_2 m v_2 = \frac{m(0.91c)}{\sqrt{1-(0.91)^2}} = 2.19\,mc$$

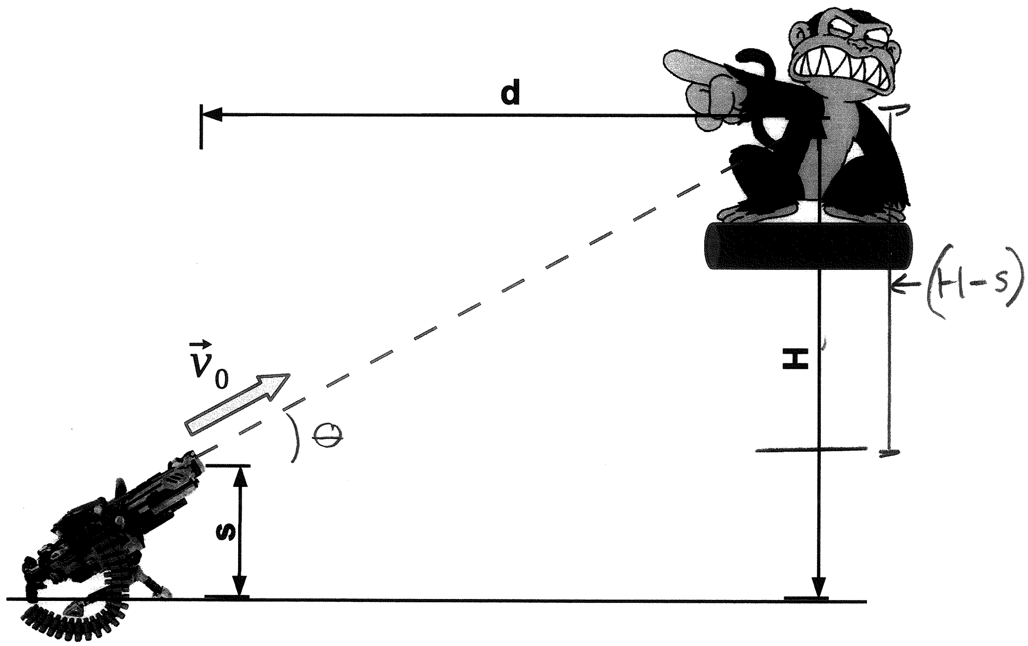
$$|\vec{F}_{net}| = \frac{|p_2 - p_1|}{\Delta t} = \frac{|2.19 - 4.9|mc}{0.25} = \frac{2.73}{0.25}mc = 10.9\,mc$$

$$= (10.9)\cdot(9\times10^{-31})(3\times10^{8}) = \underbrace{\boxed{2.95\times10^{-21}\,N = |\vec{F}_{net}|}}_{2pts}$$

Problem 3 (25 Points)

A nerf bullet is fired at a monkey in a tree a distance d away and height H above the ground. The nerf bullet leaves the gun at a height s from the ground with initial speed v_0. At the instant the bullet leaves the gun it is aimed directly at the monkey who simultaneously falls from rest out of the tree.

To earn full credit when solving the following problems please start from a fundamental principle. That is, if you use a formula not provided on the formula sheet you must start from a fundamental principle and show how you derived that equation.



(a 10pts) Determine how much time Δt passes before the monkey was hit by the nerf bullet.

$v_x = v_0 \cos\theta \quad , \quad v_y = v_0 \sin\theta$

$d = v_x \Delta t$

$\cos\theta = \dfrac{d}{\sqrt{d^2 + (H-s)^2}}$

$\Delta t = \dfrac{d}{v_x} = \dfrac{d}{v_0 \cos\theta} = \dfrac{\sqrt{d^2 + (H-s)^2}}{v_0}$

$\Delta t = \dfrac{\sqrt{d^2 + (H-s)^2}}{v_0}$

5% = 0.5
15% = 1.5
30% = 3.0
80% = 8.0

(b 15pts) Calculate the height y_{hit} from the ground that the monkey and nerf bullet collide.

$$\Delta \vec{p} = \vec{F}_{net}\,\Delta t$$

For the monkey

$$\vec{F}_{net} = -mg\hat{y} = \text{const}$$

$$\vec{p}_f - \vec{p}_i = -mg\hat{y}\,\Delta t$$

$$\vec{p}_i = 0$$

$$\vec{p}_f = -mg\hat{y}\,\Delta t$$

$$\vec{p}_f = m\vec{V}_f = \frac{2m\Delta\vec{r}}{\Delta t} = -mg\hat{y}\,\Delta t$$

$$\Rightarrow \cancel{m}\,\Delta\vec{r} = -\cancel{m}\,g\frac{\Delta t^2}{2}\,\hat{y}$$

$$\Delta\vec{r} = \Delta y\,\hat{y} = -\frac{g(\Delta t)^2}{2}\,\hat{y}$$

$$\Rightarrow (y_f - y_i) = -\frac{g(\Delta t)^2}{2}$$

$$y_f - H = -\frac{g(\Delta t)^2}{2}$$

$$y_f = y_{hit} = -\frac{g(\Delta t)^2}{2} + H$$

$$\boxed{y_{hit} = H - \frac{g}{2}\left(\frac{d^2+(H-s)^2}{V^2}\right)}$$

5% =	−1.0
15% =	−2.0
30% =	−4.5
80% =	−12

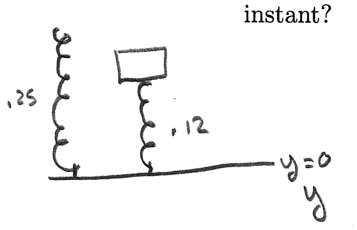
$$\vec{V}_f = 2\vec{V}_{avg} = \frac{2\Delta\vec{r}}{\Delta t}$$

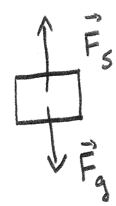
No monkeys were harmed in the making of this problem!

Problem 4 (25 Points)

A spring has a relaxed length of 0.25 m, and its stiffness is 15 N/m. The spring sits vertically on a table. You place a block of mass 0.1 kg on the spring and push down on the block until the spring is only 0.12 m long. You hold the block motionless on the compressed spring, then remove your hand.

(a 5pts) You remove your hand from the block without giving the block a shove, so that it is initially at rest even after you remove your hand. Ignoring air resistance, what is the net force on the block at this instant?





$$\vec{F}_g = -mg\hat{y} = -9.8(0.1)\hat{y}\,N = -0.98\hat{y}\,N \Big\}\, 1\,pt$$

$$\left.\begin{aligned}&\vec{F}_s = -ks\hat{y} \quad |\vec{s}| = |\vec{L}_0 - \vec{L}| = |.25 - .12| \\ &s = |0.13| = 0.13\,m \\ &k = 15\,N/m \\ &\vec{F}_s = (0.13)(15)\hat{y}\,N \\ &\quad = 1.95\hat{y}\,N\end{aligned}\right\}\, 2\,pt$$

$$\vec{F}_{net} = \vec{F}_g + \vec{F}_s \Big\}\, 1\,pt$$

$$\vec{F}_{net} = -0.98\hat{y}\,N + 1.95\hat{y}\,N$$

$$\boxed{\vec{F}_{net} = 0.97\hat{y}\,N = \langle 0, 0.97, 0\rangle\,N} \Big\}\, 1\,pt$$

(b 5pts) At a time 0.030 seconds after releasing the block determine the new momentum of the block.

$$\left.\begin{aligned}&\Delta\vec{p} = \vec{F}_{net}\,\Delta t \\ &\vec{p}_f - \vec{p}_i = \vec{F}_{net}\,\Delta t\end{aligned}\right\}\, 3\,pts$$

$$\vec{p}_i = 0 \implies \vec{p}_f = \vec{F}_{net}\,\Delta t = \langle 0, 0.97, 0\rangle \cdot 0.030\ N\cdot s\ \left(\frac{kg\,m}{s}\right) \Big\}\, 1\,pt$$

$$\boxed{\vec{p}_f = \langle 0, 0.029, 0\rangle\,\frac{kg\,m}{s}} \Big\}\, 1\,pt$$

(c 10pts) At a time 0.030 seconds after releasing the block determine the new position of the block.

$\vec{p} = m\vec{v}$

$\dfrac{\vec{p}_f + \vec{p}_i}{2} = \vec{p}_{avg} = \dfrac{(0.029 + 0)}{2}\hat{y} = 0.0145\hat{y}\ \dfrac{kg \cdot m}{s}$

$\Rightarrow \vec{v}_{avg} = \dfrac{\vec{p}_{avg}}{m} =$

$\vec{v}_{avg} = \dfrac{0.0145\hat{y}}{0.1} = 0.145\ m/s\ \hat{y} = \langle 0, 0.145, 0\rangle\ m/s$

$\vec{r} = \vec{v}_{avg} \cdot \Delta t + \vec{r}_o = \langle 0, 0.145, 0\rangle\ m/s \cdot 0.030\ s + \langle 0, .12, 0\rangle\ m$

$\vec{r} = \langle 0, 0.004365, 0\rangle m + \langle 0, .12, 0\rangle m$

$\boxed{\vec{r} = \langle 0, 0.12437, 0\rangle m}$

5%	= −0.5
15%	= −1.5
30%	= −3.0
80%	= −8.0

(d 5pts) What is the net force acting on the block at this time (0.030 s after release)?

$\vec{L} = |\vec{r}|\hat{y}$

$|\vec{s}| = |0.25 - 0.12437|\ m = 0.1256 m$

$\vec{F}_g = \langle 0, -0.98, 0\rangle N$

$\vec{F}_s = (15 \cdot 0.1256)\hat{y} = \langle 0, 1.88, 0\rangle N$

3 pts

$\vec{F}_{net} = \vec{F}_g + \vec{F}_s = \langle 0, -0.98, 0\rangle N + \langle 0, 1.88, 0\rangle N$ 1 pt

$\boxed{\vec{F}_{net} = \langle 0, 0.905, 0\rangle N}$ 1 pt

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

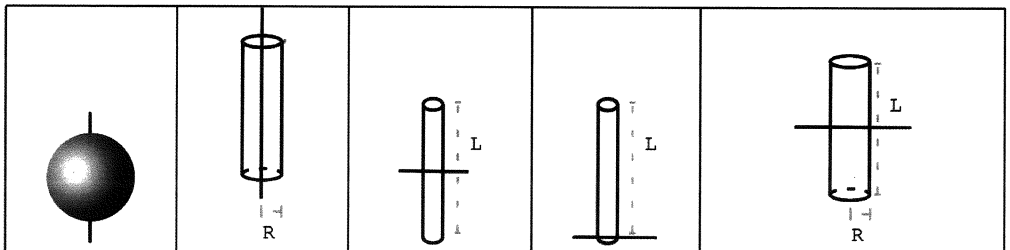
$$E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1, 2, 3\ldots$$

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

Moment of 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}