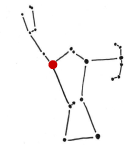
PHYS 2211 Test 1
Fall 2015

Name(print) Test Key **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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^4$
- 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.

Honor Pledge

"In accordance with the Georgia Tech Honor Code, I have neither given nor received unauthorized aid on this test."

Betelgeuse

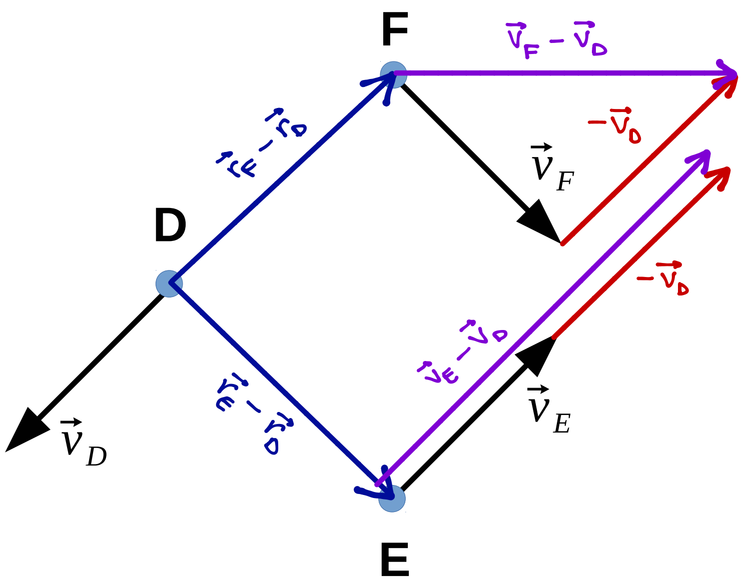
Sign your name on the line above

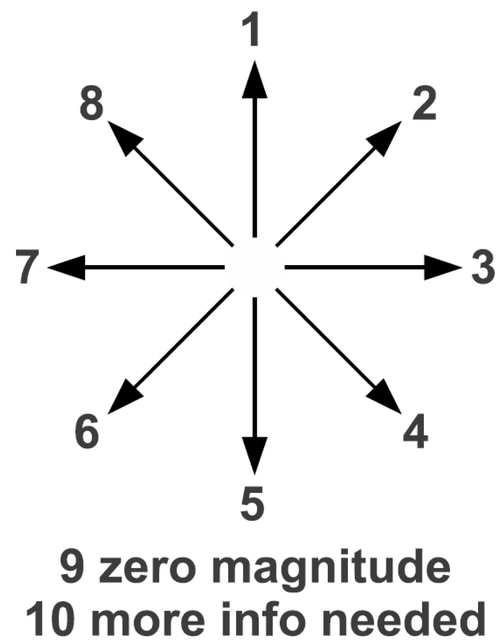
Please do not write on this page

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

`Problem 1 (25 Points)`

The position of an object at three different times is indicated by dots in the figure shown. The object is initially located at position D at time t_D. Later, the object is observed to be at E at time $t_E > t_D$. Finally, the object is observed to be at position F at time $t_F > t_E$. The arrows shown at each location represent the object's velocity at that location; the object's speed is the same for all locations shown.





1pt each

(a 10pts) Using the numbered direction arrows shown, indicate (by number) which direction arrow best represents the direction of the quantities listed below. If the quantity has zero magnitude or cannot be determined, indicate using the corresponding number listed below.

The position vector at location D __10__

The change in position (the displacement) between location D and location F __2__

The change in velocity between location D and location F __3__

The change in momentum between location D and location F __3__

The average net force between location D and location F __3__

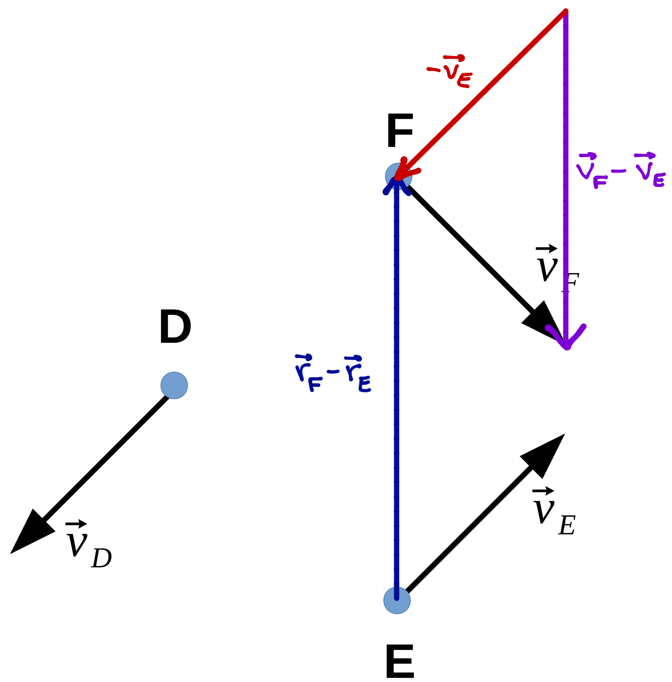
The position vector at location E __10__

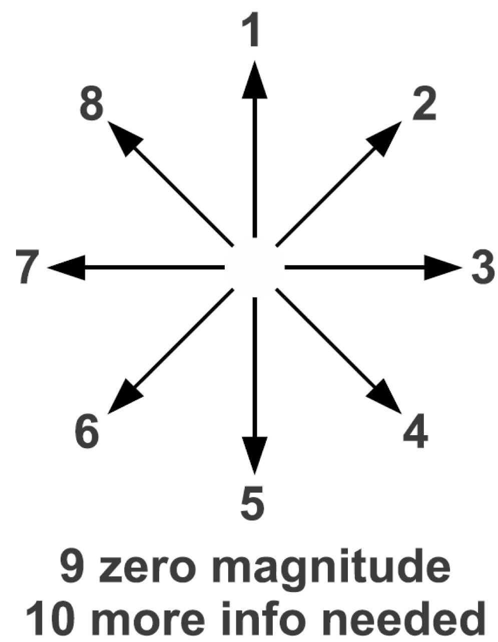
The change in position (the displacement) between location D and location E __4__

The change in velocity between location D and location E __2__

The change in momentum between location D and location E __2__

The average net force between location D and location E __2__





1pt each

(b 5pts) Using the numbered direction arrows shown, indicate (by number) which direction arrow best represents the direction of the quantities listed below. If the quantity has zero magnitude or cannot be determined, indicate using the corresponding number listed below.

The position vector at location F ___10___

The change in position (the displacement) between location E and location F ___1___

The change in velocity between location E and location F ___5___

The change in momentum between location E and location F ___5___

The average net force between location E and location F ___5___

2 pts each

(c 10pts) Write "T" next to each true statement below, and write "F" for every false statement.

___F___ The displacement vector for an object can be in a different direction than its average velocity (during the same time interval).

___F___ An object's momentum is always in the same direction as the acceleration on that object.

___F___ The change in an object's momentum can be in a different direction than the net force on the object.

___T___ An object's momentum and its instantaneous velocity are always in the same direction.

___T___ If the net force on an object is constant, then the rate of change of its momentum is constant.

Problem 2 (25 Points)

Dr Greco gave you a computer program to predict iteratively the motion of a falling ball; however, you discover the program is missing a few lines of code. In the space provided in the body of the script, add the statements necessary to complete the code. **All numerical values are in SI units**.

```
GlowScript 1.1 VPython
ball = sphere(pos=vector(0,10.8,0), radius=0.1, color=color.green)
mball = .48
vball = vector(0, -0.14, 0)
pball = mball*vball
deltat = 0.5
t = 0
g=9.8
```

All (a 3pts) Circle the line of code that correctly describes the net force on the falling ball.

```
Fnet = mg

Fnet = vector(0,-mg,0)

Fnet = vector(0,-mball*g,0)

Fnet = -mball*g

Fnet = <0,-mg,0>

Fnet = vector(0,-g,0)

while t < 1.1:
    rate(100)
```

(b 9pts) Add statements **here** to update the momentum and the position of the ball. Approximate the average velocity using $\vec{v}_{avg} \approx \vec{v}_f$.

Method 1

```
pball = pball + Fnet * deltat
ball.pos = ball.pos + (pball/mball) * deltat
```

Method 2

```
vball = vball + (Fnet/mball) * deltat
pball = mball * vball
ball.pos = ball.pos + vball * deltat
```

```
    t = t + deltat
```

Either method is ok
✓ 5 pts for momentum
✓ 4 pts for position
Incorrect syntax/variables:
-0.5 pt each

Please refer to the code on the previous page to answer the following questions:

All (c 2pts) What is the initial position of the ball? (Answer should be a vector with numerical components in the proper units.)

$$\boxed{\vec{r}_i = \langle 0,\ 10.8,\ 0 \rangle \text{ m}}$$

All (d 2pts) What is the initial momentum of the ball? (Answer should be a vector with numerical components in the proper units.)

$$\vec{p}_i = m\vec{v}_i = (0.48)\langle 0, -0.14, 0 \rangle = \boxed{\langle 0, -0.0672, 0 \rangle \text{ kg m/s}}$$

All (e 2pts) What is the net force on the ball? (Answer should be a vector with numerical components in the proper units.)

$$\vec{F}_{net} = \langle 0, -mg, 0 \rangle = \langle 0, (-0.48)(9.8), 0 \rangle = \boxed{\langle 0, -4.704, 0 \rangle \text{ N}}$$

(f 7pts) Using the initial position, initial momentum and net force that you indicated in parts (c-e), start from the momentum principle and compute the ball's momentum and position in one iterative step with $\Delta t = 0.5$ s. Approximate the average velocity using $\vec{v}_{avg} \approx \vec{v}_f$. Your answer should be in vector form and have SI units.

$$\underbrace{\vec{p}_f = \vec{p}_i + \vec{F}_{net}\Delta t}_{2\text{ pts}} = \langle 0, -0.0672, 0 \rangle + (0.5)\langle 0, -4.704, 0 \rangle =$$

$$= \langle 0, -0.0672, 0 \rangle + \langle 0, -2.352, 0 \rangle = \boxed{\langle 0, -2.4192, 0 \rangle \text{ kg m/s}}$$

2 pts

$$\underbrace{\vec{r}_f = \vec{r}_i + \frac{\vec{p}_f}{m}\Delta t}_{2\text{ pts}} = \langle 0, 10.8, 0 \rangle + \left(\frac{0.5}{0.48}\right)\langle 0, -2.4192, 0 \rangle =$$

$$= \langle 0, 10.8, 0 \rangle + \langle 0, -2.52, 0 \rangle = \boxed{\langle 0, 8.28, 0 \rangle \text{ m}}$$

1 pt

* Watch for POE *
(propagation of error)

Problem 3 (25 Points)

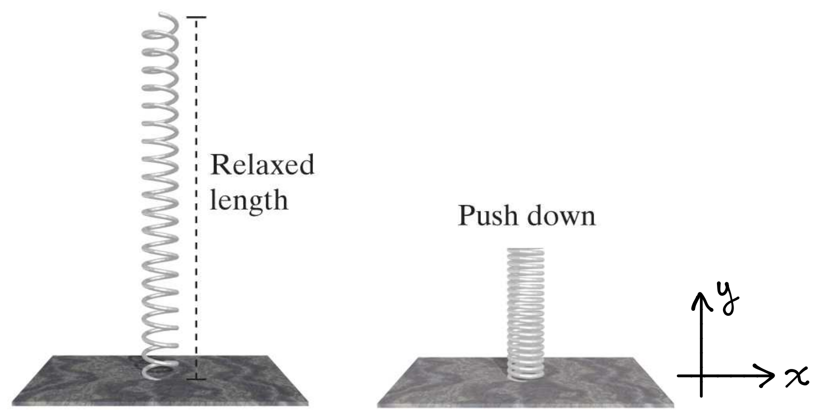
Doctor Greco has signed on to be part of the human colony for Mars-One by 2027. One of his first assignments will be to study the dynamics of springs in his new world.

All

(a 5pts) In his first experiment, Dr. Greco calculates the effective acceleration g on the surface of Mars. The mass of Mars is 6.39×10^{23} kg and it has a radius of 3.39 million meters. Determine the value Dr. Greco would expect to find. Your answer should be in SI units.

$$\cancel{m}g = \frac{GM\cancel{m}}{r^2} \Rightarrow g = \frac{GM}{r^2} = \frac{(6.7e-11)(6.39e23)}{(3.39e6)^2} = \boxed{3.7\ m/s^2}$$

For his second experiment, Dr. Greco stands a spring of stiffness 8.7 N/m vertically on the surface of Mars and then adds a small block of mass of 60 grams so that the spring length changes from a rest length value of 28 cm to 20 cm. He made sure the block is at rest before releasing it at time $t = 0$ as indicated in the diagram.



(b 10pts) What is the net force on the block at time $t = 0$? Your answer should be a vector and in SI units.

$$\checkmark\ \vec{F}_{grav} = \langle 0, -mg, 0 \rangle = \langle 0, (-0.060)(3.7), 0 \rangle = \langle 0, -0.222, 0 \rangle \text{ N}$$

$$\checkmark\ \vec{F}_{spring} = -k_s s \hat{L} = -k_s (L - L_0) \langle 0, 1, 0 \rangle =$$

$$= -(8.7)(0.20 - 0.28) \langle 0,1,0 \rangle = -(8.7)(-0.08) \langle 0,1,0 \rangle =$$

$$= (0.696) \langle 0,1,0 \rangle = \langle 0, 0.696, 0 \rangle \text{ N}$$

$$\Rightarrow \vec{F}_{net} = \vec{F}_{grav} + \vec{F}_{spring} = \langle 0, -0.222, 0 \rangle + \langle 0, 0.696, 0 \rangle =$$

$$\boxed{\vec{F}_{net} = \langle 0, 0.474, 0 \rangle \text{ N}}$$

−0.5 clerical
−1.5 minor
−3.0 major
−8.0 BTN

(c 10pts) Determine the <u>position</u> of the block <u>0.2 seconds later</u>. **Apply the momentum principle in *two* times steps of 0.1 seconds.** Your answer should be a vector and in SI units.

$$\vec{v}_1 = \cancel{\vec{v}_0}^{\,0} + \frac{\vec{F}_{net}}{m}\Delta t = \left(\frac{0.1}{0.060}\right)\langle 0, 0.474, 0\rangle = \langle 0, 0.79, 0\rangle \ \text{m/s}$$

$$\vec{r}_1 = \vec{r}_0 + \vec{v}_1 \Delta t = \langle 0, \overbrace{0.20}^{L}, 0\rangle + (0.1)\langle 0, 0.79, 0\rangle =$$

$$= \langle 0, 0.20, 0\rangle + \langle 0, 0.079, 0\rangle = \langle 0, 0.279, 0\rangle \ \text{m}$$

$$\vec{F}^{New}_{spring} = -k_s\, s\, \hat{L} = -(8.7)(0.279 - 0.28)\langle 0,1,0\rangle = -(8.7)(-0.001)\langle 0,1,0\rangle =$$

$$= (0.0087)\langle 0,1,0\rangle = \langle 0, 0.0087, 0\rangle \ \text{N}$$

$$\vec{F}^{NEW}_{net} = \vec{F}_{grav} + \vec{F}^{NEW}_{spring} = \langle 0, -0.222, 0\rangle + \langle 0, 0.0087, 0\rangle = \langle 0, -0.2133, 0\rangle \ \text{N}$$

$$\vec{v}_2 = \vec{v}_1 + \frac{\vec{F}^{NEW}_{net}}{m}\Delta t = \langle 0, 0.79, 0\rangle + \left(\frac{0.1}{0.060}\right)\langle 0, -0.2133, 0\rangle =$$

$$= \langle 0, 0.79, 0\rangle + \langle 0, -0.3555, 0\rangle = \langle 0, 0.4345, 0\rangle \ \text{m/s}$$

$$\vec{r}_2 = \vec{r}_1 + \vec{v}_2 \Delta t = \langle 0, 0.279, 0\rangle + (0.1)\langle 0, 0.4345, 0\rangle =$$

$$= \langle 0, 0.279, 0\rangle + \langle 0, 0.04345, 0\rangle = \langle 0.\ 0.32245, 0\rangle \ \text{m}$$

$\Rightarrow$ The position of the block 0.2 seconds later is:

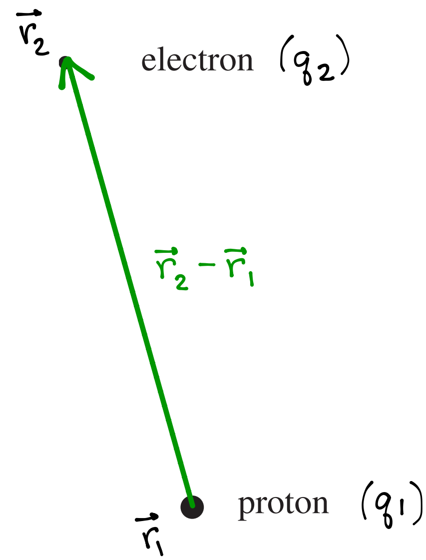
$$\boxed{\vec{r}_f = \langle 0, 0.32245, 0\rangle \ \text{m}}$$

* Watch for <u>POE</u> *

−0.5 clerical
−1.5 minor
−3.0 major
−8.0 BTN

Problem 4 (25 Points)

A proton (charge $q_1 = +1.6 \times 10^{-19}$ C) is at location $\vec{r}_1 = \langle\ 5 \times 10^{-6},\ 2 \times 10^{-6},\ 0 \rangle$ m and an electron (charge $q_2 = -1.6 \times 10^{-19}$ C) is located at $\vec{r}_2 = \langle\ 3 \times 10^{-6},\ 9 \times 1010^{-6},\ 0 \rangle$ m. The proton and electron are in outer space, far from any other objects.



(a 6pts) Determine the relative position vector that points from the proton to the electron. Your answer should be a vector and in SI units.

$$\vec{r} = \underbrace{\vec{r}_2 - \vec{r}_1}_{4\text{ pts}} = \langle 3e{-6}, 9e{-6}, 0 \rangle - \langle 5e{-6}, 2e{-6}, 0 \rangle =$$

$$= \boxed{\langle -2e{-6}, 7e{-6}, 0 \rangle \text{ m}}$$

2 pts

All

(b 3pts) What is the unit vector that points from the proton to the electron? Your answer should be a vector.

$$|\vec{r}| = \sqrt{(-2e{-6})^2 + (7e{-6})^2 + 0} = \sqrt{5.3e{-11}} = 7.28e{-6} \text{ m}$$

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\langle -2e{-6}, 7e{-6}, 0 \rangle \cancel{m}}{7.28e{-6}\ \cancel{m}} = \boxed{\langle -0.275, 0.962, 0 \rangle}$$

* Watch for POE *

(c 8pts) Determine the magnitude of the electric force on the electron due to the proton. Your answer should be in SI units.

$$|\vec{F}_{elec}| = \frac{1}{4\pi\epsilon_0}\frac{|q_1||q_2|}{|\vec{r}|^2} = \frac{(9e9)(1.6e-19)(1.6e-19)}{5.3e-11} =$$

$$= \boxed{4.347e-18 \text{ N}}$$

−0.5 clerical
−1.0 minor
−2.5 major
−6.5 BTN

* Watch for POE *

All (d 5pts) Determine the electric force on the electron due to the proton. Your answer should be a vector and in SI units.

$$\vec{F}_{elec} = |\vec{F}_{elec}|(-\hat{r}) = (4.347e-18)\langle 0.275, -0.962, 0\rangle =$$

$$= \boxed{\langle 1.195e-18, -4.182e-18, 0\rangle \text{ N}}$$

* Watch for POE *

All (e 3pts) Determine the electric force on the proton due to the electron. Your answer should be a vector and in SI units.

Due to reciprocity, $\vec{F}_{on\ proton} = -\vec{F}_{on\ electron}$

$$\Rightarrow \boxed{\vec{F}_{on\ proton} = \langle -1.195e-18, 4.182e-18, 0\rangle \text{ N}}$$

* Watch for POE *

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

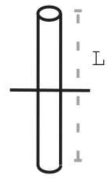
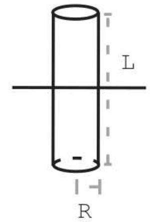
$$\text{prob}(E)\propto\Omega\,(E)\,e^{-\frac{E}{kT}} \qquad E_N=-\frac{13.6\text{eV}}{N^2} \text{ where } N=1,2,3\ldots$$

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

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}