PHYS 2211 Midterm 1
Spring 2014

Name(print) Key **Lab Section** ∞

Greco(M), Schatz(N)			
Day	12-3pm	3-6pm	6-9pm
Tuesday	M01 N01	M02 N02	M03 N03
Thursday	M04 N04	M05 N05	M06 N06

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."

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Sign your name on the line above

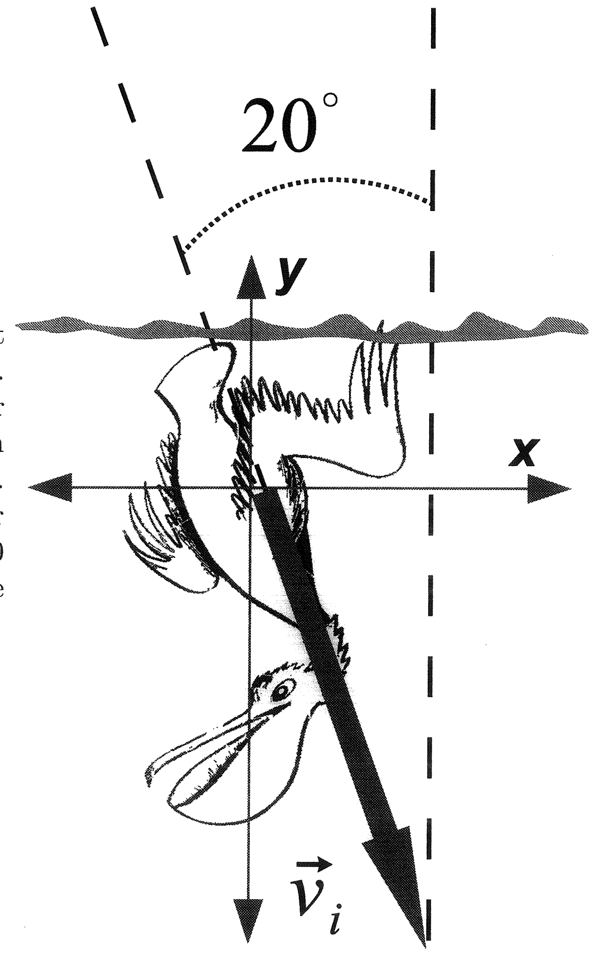
PHYS 2211

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)

In a recent lab, you studied the motion of an object falling under the forces of gravity and air resistance. Your friend has asked you to help her with a similar experiment that involves testing a model for the motion of a pelican as it dives below the surface of the ocean. From direct observation she knows that pelicans enter the water with a speed of 15 m/s and at an angle of 20 degrees from a vertical line draw perpendicular to the surface of the water as indicated in the diagram.



Current pelican theory predicts that as they dive through the water they experience a drag force proportional to their speed cubed v^3. The code listed on the next page, which is nearly identical to your computer model from lab, is missing a few lines of code. In the spaces provided, add the statements necessary to predict the motion of the pelican.

```
from __future__ import division
from visual import *

# Create object for visualization
pelican = sphere(color=color.brown, radius = 0.22)
pelican.m = 15 #mass of a pelican in kg

#Initial Conditions
pelican.pos = vector(0,0,0) #Take the point of entry into the water to be the origin.
```

(a 5pts) Add in the initial velocity of the pelican as it enters the water.

5 `pelican.vel =` vector(15sin(20), -15cos(20), 0)

```
t = 0  #the time when we choose to start our clock
deltat = 0.001 #the time step
g=9.81 gravitational acceleration on Earth
b=1.2 proportionality constant, b, for magnitude of drag force

# ============================================
while t < 1.:
```

(b 20pts) Add the necessary code to update the position of the pelican.

4 F_{Earth} = vector(0, -g*pelican.m, 0)

4 F_{Air} = -b* pelican.vel * mag2(pelican.vel)

4 F_{net} = F_{Earth} + $\vec{F}_{Air}$

4 pelican.vel = pelican.vel + F_{net}/pelican.m * deltat

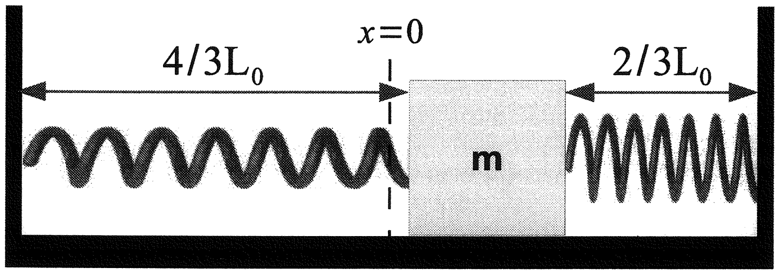
4 pelican.pos = pelican.pos + pelican.vel * deltat

Note; no penalty if student Attempts to include a buoyant force

```
    t = t + deltat
print(t,pelican.pos)
```

Problem 2 (25 Points)

A block of mass m is connected to two springs. Each spring has a relaxed length L_0, the spring on the left has a stiffness k_s and the spring on the right has a stiffness $2k_s$. As shown in the diagram, the block is initially released from rest at $x = L_0/3$. The bottom surface supporting the block is frictionless.



(a 5pts) Choose the block as the system, and use the usual axis system with the +x to the right and +y running vertically up. Just after you release the block, which external objects are interacting with the chosen system?

(1) Left spring
(1) Right Spring
(1) EArth
(2) Bottom surface

(b 5pts) At the instant you release the block, what is the net force on the block? Your answer must be expressed as a vector.

(1) $\frac{dp_y}{dt} = 0 \Rightarrow F_{y,net} = 0$

(1) $\vec{F}_{spring,Left} = -K_s\left(\frac{4}{3}L_0 - L_0\right)\hat{x}$ since $\hat{L} = \langle 1,0,0\rangle$

(2) $\vec{F}_{spring,right} = -2K_s\left(\frac{2}{3}L_0 - L_0\right)(-\hat{x})$ since $\hat{L} = \langle -1,0,0\rangle$

(1) $\vec{F}_{net} = \langle -K_s L_0, 0, 0\rangle$

(c 5pts) Determine the new velocity of the block a short time Δt after being released. Here Δt should be taken as a given. Your answer must be expressed as a vector.

3 $\vec{V}_f = \vec{V}_i + \vec{F}_{net}/_m \, \Delta t$

2 $\vec{V}_f = \langle -K_s L_0, 0, 0 \rangle \dfrac{\Delta t}{m} = \langle -\dfrac{K_s}{m} L_0 \Delta t, 0, 0 \rangle$

(d 5pts) using your answer from part (c) calculate the new position of the block. Your answer must be expressed as a vector.

2 $\vec{V}_{AVG} \approx \vec{V}_f = \langle -\dfrac{K_s}{m} L_0 \Delta t, 0, 0 \rangle$

2 $\vec{r}_f = \vec{r}_i + \vec{V}_{AVG} \Delta t = \langle \dfrac{L_0}{3}, 0, 0 \rangle + \langle -\dfrac{K_s}{m} L_0 \Delta t, 0, 0 \rangle \Delta t$

1 $\vec{r}_f = \langle \dfrac{L_0}{3} - \dfrac{K_s}{m} L_0 \Delta t^2, 0, 0 \rangle$

(e 5pts) Determine the new force on the block. Your answer must be expressed as a vector.

2 $\vec{F}_{s,L} = -K_s \left(\dfrac{4}{3} L_0 - \dfrac{K_s}{m} L_0 \Delta t^2 - L_0 \right) \hat{x}$

2 $\vec{F}_{s,R} = -2K_s \left(\dfrac{2}{3} L_0 + \dfrac{K_s}{m} L_0 \Delta t^2 - L_0 \right) (-\hat{x})$

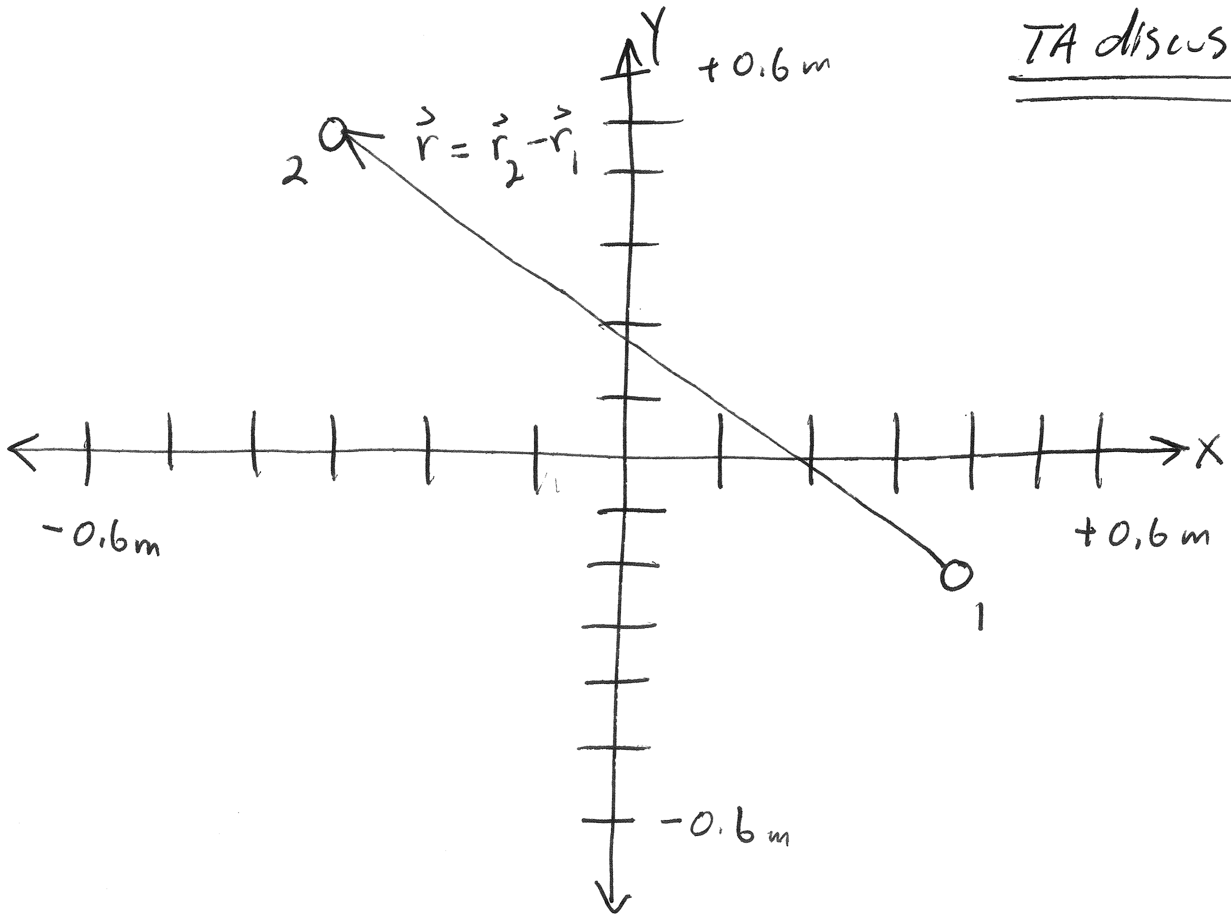
1 $\vec{F}_{net} = \langle -K_s L_0 + 3 \dfrac{K_s^2}{m} L_0 \Delta t^2, 0, 0 \rangle$

Problem 3 (25 Points)

Two thin hollow plastic spheres, about the size of a ping-pong ball with masses $m_1 = m_2 = 2 \times 10^{-3}$ kg have been rubbed with wool. Sphere 1 has a charge $q_1 = -3 \times 10^{-9}$ C and is at location $< 40 \times 10^{-2}, -20 \times 10^{-2}, 0 >$ m. Sphere 2 has a charge $q_2 = -6 \times 10^{-9}$ C and is at location $< -30 \times 10^{-2}, 50 \times 10^{-2}, 0 >$ m.

(a 5pts) Draw a diagram of the situation showing the positions of the charges.

TA discuss



(b 5pts) What is the relative position vector pointing from q_1 to q_2?

(2) $\vec{r} = \vec{r}_2 - \vec{r}_1 = \langle -0.3, 0.5, 0 \rangle m - \langle 0.4, -0.2, 0 \rangle m$

(2)

(1) $\vec{r} = \langle -0.7, 0.7, 0 \rangle m$

(c 5pts) Calculate a unit vector pointing in the direction of the electric force acting on q_2?

(2) $\hat{r} = \frac{\vec{r}}{|\vec{r}|}$ where $|\vec{r}|^2 = r_x^2 + r_y^2 + r_z^2$ (2)

$|\vec{r}| = (0.7^2 + 0.7^2)^{1/2} = 0.7\sqrt{2}$ m

(1) $\hat{r} = \frac{\langle -0.7, 0.7, 0 \rangle \text{ m}}{0.7\sqrt{2} \text{ m}} = \langle -\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0 \rangle$

(d 5pts) Determine the vector electric force on q_2 by q_1?

(1) $\vec{F}_{elec} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{|\vec{r}|^2} \hat{r} = \frac{(9E9)(-3E-9)(-6E-9)}{(0.7\sqrt{2})^2} \langle -1, 1, 0 \rangle \frac{1}{\sqrt{2}}$ N (1) (1) (1)

(1) $\vec{F}_{elec} = \langle -1.17 \times 10^{-7}, 1.17 \times 10^{-7}, 0 \rangle$ N

(e 5pts) If the distance between the two spheres were increased by a factor of five, how would the magnitude of the electric force change?

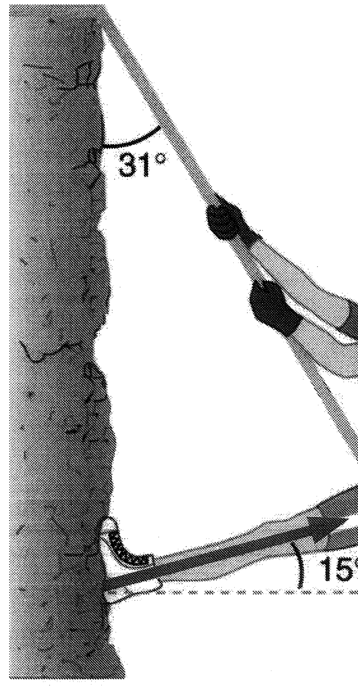
$|\vec{F}| = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_2|}{r^2}$ if $r \to 5r$ then $|\vec{F}'| = \frac{1}{4\pi} \frac{|q_1 q_2|}{(5r)^2}$ (3)

AND $|\vec{F}'| = \frac{1}{25} |\vec{F}|$ (1)

→ it would be reduced by a factor of $\frac{1}{25}$ (1)

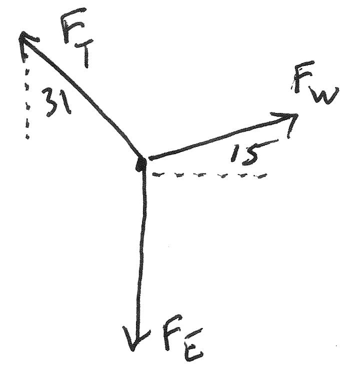
Problem 4 (25 Points)

Consider a rock climber of mass $m = 60$ kg who is ascending a vertical wall and stops for a rest by leaning back on her rope as seen in the diagram. The rope has some unknown tension and makes and angle of 31 degrees with the vertical. As the climber rest, the wall exerts a force $\vec{F}$ of unknown magnitude. This force $\vec{F}$ points at an angle of 15 degrees above the horizontal, as shown in the figure.



−0.5 C
−1.5 Minor
−3.0 Major
−8.0 BTN

(a 10pts) Determine the magnitude of the tension in the rope required for the mountain climber to remain stationary. Please start from a fundamental principle and show your work.



$$\frac{d\vec{p}}{dt} = 0 \text{ then by } 2^{nd} \text{ LAW } \vec{F}_{net} = 0$$

$$\vec{F}_{net} = \vec{F}_{tension} + \vec{F}_{wAll} + \vec{F}_{earth} = 0$$

x-direction $\quad |\vec{F}_{wAll}| \cos 15^\circ - |\vec{F}_{Tension}| \sin 31^\circ = 0$

y-direction $\quad |\vec{F}_{tension}| \cos 31^\circ - mg + |\vec{F}_w| \sin 15^\circ = 0$

$$F_T \cos 31 = mg - \left(F_T \frac{\sin 31}{\cos 15} \sin 15 \right)$$

$$F_T (\cos 31 + \sin 31 \tan 15) = mg$$

$$|\vec{F}_{Tension}| = \frac{mg}{(\cos 31 + \sin 31 \tan 15)} = \frac{(60\text{Kg})(9.81\ m/s^2)}{0.99517} = \boxed{591\ N}$$

(b 10pts) Determine the magnitude of the wall force $\vec{F}$ required for the mountain climber to remain stationary. Please start from a fundamental principle and show your work.

from (a) $F_{net,x} = 0 \Rightarrow |\vec{F}_{WALL}| \cos 15^\circ - |\vec{F}_{tension}| \sin 31^\circ = 0$

$$|\vec{F}_{WALL}| = |\vec{F}_{tension}| \cancel{\tan 15^\circ} \frac{\sin 31^\circ}{\cos 15^\circ}$$

$$= (591\ N)(0.533)$$

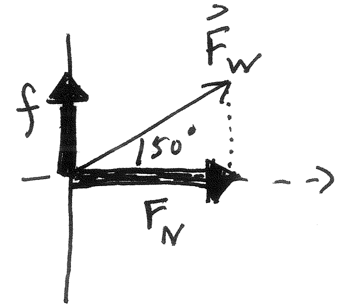
$$= \boxed{315\ N}$$

-0.5 C
-1.5 Minor
-3.0 Major
-8.0 BTN

(c 5pts) Calculate the minimum static coefficient of friction, between the climbers shoes and the cliff, required to remain motionless in the position shown.

1 $|\vec{f}_{riction}| \le \mu_s |\vec{F}_N|$ $\quad$ MAX $(|\vec{f}_{riction}|) = \mu_s |\vec{F}_N|$

1 → before the shoe slips the friction force will be maximum



1 $|\vec{F}_N| = |\vec{F}_{WALL}| \cos 15^\circ$

1 $|\vec{f}_{riction}| = |\vec{F}_{WALL}| \sin 15^\circ$

then $\mu_s |\vec{F}_{WALL}| \cos 15^\circ = |\vec{F}_{WALL}| \sin 15^\circ$

$\mu_s = \tan 15^\circ = 0.268$ 1

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

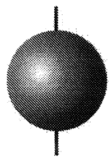
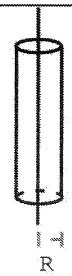
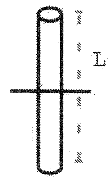
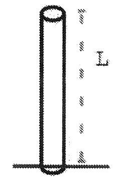
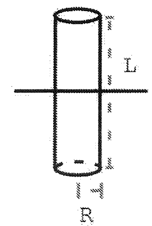
$$\text{prob}(E) \propto \Omega(E)\, e^{-\frac{E}{kT}} \qquad E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1, 2, 3\ldots$$

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

Moment of intertia for rotation about indicated axis

The cross product

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

				
$I = \frac{2}{5} M R^2$	$I = \frac{1}{2} M R^2$	$I = \frac{1}{12} M L^2$	$I = \frac{1}{3} M L^2$	$I = \frac{1}{12} M L^2 + \frac{1}{4} M R^2$

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}