PHYS 2211 Test 1
Spring 2013

Name(print) ☆ KEY ☆ Lab Section 11

Fenton(K), Curtis(N), Greco(HP/M)			
Day	12-3pm	3-6pm	6-9pm
Monday	M01 K01	M02 N01	
Tuesday	M03 N03	M04 K03	K02 N02
Wednesday	K05 N05	M05 N06	M06 K06
Thursday	K07 N07	M07 K08	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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^4$
- 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."

Firelord Azula

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.

$$\frac{d\vec{p}}{dt} = \vec{F}_{net}$$

All or nothing

-or-

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

-or

$$\vec{p}_f = \vec{p}_i + \vec{F}_{net}(t_f - t_i)$$

(etc)

−0.5
−1.0
−2.5
−6.5

(b 8pts) The position of a golf ball relative to the tee changes from < 50, 20, 30 > m to < 53, 18, 31 > m in 0.1 second. Determine the unit vector that points in the direction of the average velocity during this short time interval.

$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i = \langle 53, 18, 31\rangle \text{m} - \langle 50, 20, 30\rangle \text{m}$$

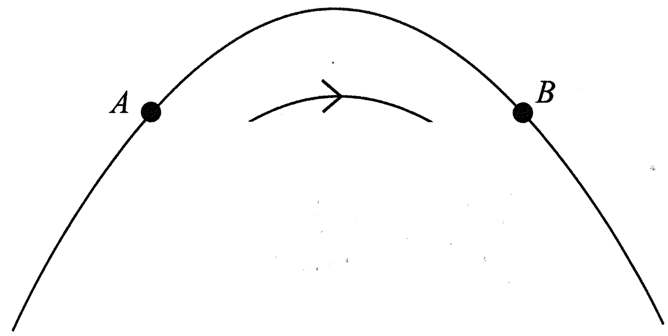
$$\Delta\vec{r} = \langle 3, -2, 1\rangle \text{ m}$$

$$\vec{v}_{Avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\langle 3, -2, 1\rangle \text{m}}{0.1 \text{ s}} = \langle 30, -20, 10\rangle \text{ m/s}$$

$$|\vec{v}_{Avg}| = \sqrt{30^2 + (-20)^2 + 10^2} = \sqrt{1400} = 37.42 \text{ m/s}$$

$$\hat{v}_{Avg} = \frac{\vec{v}_{Avg}}{|\vec{v}_{Avg}|} = \frac{\langle 30, -20, 10\rangle \cancel{\text{m/s}}}{37.42 \cancel{\text{m/s}}} =$$

$$\boxed{\hat{v}_{Avg} = \langle 0.80, -0.53, 0.27\rangle}$$



A ball kicked into the air moves along the path shown above; it is at point A and then later at point B.

(c 4pts) Which arrow best indicates the direction of the ball's instantaneous velocity at point B?

A. ↑ B. → C. ↓ D. ↘ E. ↗

(d 4pts) Which arrow best indicates the direction of the ball's average velocity from point A to point B?

A. ↑ B. → C. ↓ D. ↘ E. ↗

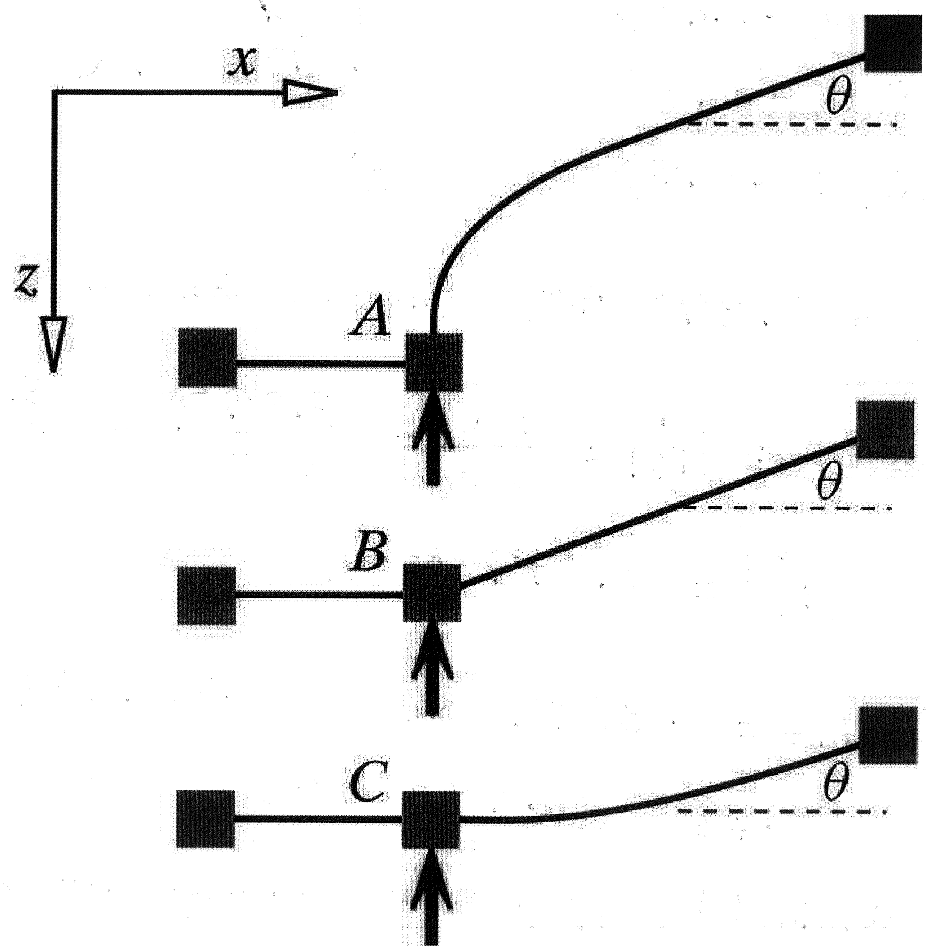
(e 4pts) Which arrow best indicates the direction of the change in the ball's momentum from point A to point B?

A. ↑ B. → C. ↓ D. ↘ E. ↗

All

Problem 2 (25 Points)

A 0.75 kg block of ice is sliding by you on a very slippery floor at 4.5 m/s. As it goes by, you give it a kick perpendicular to its path. Your foot is in contact with the ice block for 0.002 seconds. The block eventually slides at an angle of 30 degrees from its original direction (labeled θ in the diagram). The overhead view shown in the diagram is approximately to scale. The arrow represents the average force your toe applies briefly to the block of ice.



(a 5pts) Circle the letter corresponding to the correct overhead view of the ball's path:

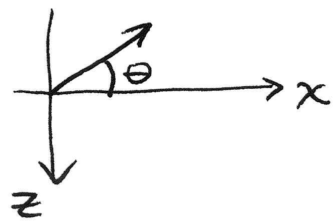
A B C

A1/

(b 20pts) Determine the magnitude of the average force you applied to the block. To earn full credit you must show your work.

$$\vec{P}_i = m\vec{v}_i = (0.75\ \text{kg})\langle 4.5, 0, 0\rangle \text{m/s} = \langle 3.375, 0, 0\rangle\ \text{kg m/s}$$

$$\hat{P}_f = \langle \cos\theta, 0, -\sin\theta\rangle$$
$$= \langle \cos 30^\circ, 0, -\sin 30^\circ\rangle$$
$$= \langle 0.866, 0, -0.5\rangle$$



$$P_{fx} = P_{ix} = 3.375\ \text{kgm/s}$$ (no force acting on x direction)

$$P_{fx} = |\vec{P}_f|\cos\theta \Rightarrow |\vec{P}_f| = \frac{P_{fx}}{\cos\theta} = \frac{3.375}{\cos 30^\circ} = \frac{3.375}{0.866}$$

$$|\vec{P}_f| = 3.897\ \text{kg m/s}$$

$$P_{fz} = -|\vec{P}_f|\sin\theta = -(3.897)\sin 30^\circ = (-3.897)(0.5)$$
$$P_{fz} = -1.949\ \text{kg m/s}$$

Net force is obtained by applying the momentum principle, in the z-direction only:

$$P_{fz} = \cancel{P_{iz}}^{\,0} + |\vec{F}_{net,z}|\Delta t$$
$$-1.949 = |\vec{F}_{net,z}|(0.002)$$
$$|\vec{F}_{net,z}| = \left|\frac{-1.949}{0.002}\right|$$
$$\boxed{|\vec{F}_{net}| = 974.5\ \text{N}}$$

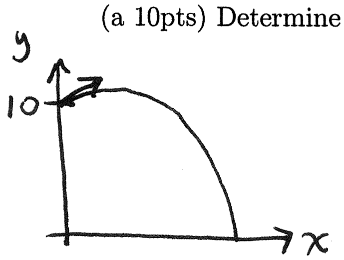
-1.0
-3.0
-6.0
-16

Problem 3 (25 Points)

Dr. Greco stands at the top of a diving board with initial position $< 0, 10, 0 >$ m and jumps with an initial velocity $< 0.8, 4.5, 0 >$ m/s to dive into a pool on the ground below. For this problem you should neglect air resistance. Start this problem by making a sketch/diagram below.

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 it takes for Dr. Greco to hit the pool.



$$\vec{P}_f = \vec{P}_i + \vec{F}_{net}\,\Delta t$$

Force only in $-y$ direction (gravity)

$$\underset{0}{\cancel{y_f}} = y_i + v_{iy}\Delta t - \tfrac{1}{2} g \Delta t^2$$

$$0 = y_i + v_{iy}\Delta t - \tfrac{1}{2} g \Delta t^2$$

$$0 = 10 + (4.5)\Delta t - \tfrac{1}{2}(9.8)\Delta t^2$$

Quadratic: $\Delta t = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ with: $\begin{cases} a = -\frac{1}{2}(9.8) = -4.9 \\ b = 4.5 \\ c = 10 \end{cases}$

$$\Delta t = \frac{(-4.5) \pm \sqrt{(4.5)^2 - (4)(-4.9)(10)}}{(2)(-4.9)} =$$

$$= \frac{(-4.5) \pm \sqrt{20.25 + 196}}{-9.8} = \frac{-4.5 \pm \sqrt{216.25}}{-9.8} =$$

$$= \frac{-4.5 \pm 14.71}{-9.8} = \begin{cases} \dfrac{-4.5 + 14.71}{-9.8} = -1.04 & \text{NOPE! Time can't be negative} \\[2ex] \dfrac{-4.5 - 14.71}{-9.8} = 1.96 & \text{GOOD!} \end{cases}$$

$$\boxed{\Delta t = 1.96 \text{ sec}}$$

−0.5
−1.5
−3.0
−8.0

(b 5pts) What should the minimum length of the pool be (in the x direction) such that Dr. Greco can safely land in the water?

$$3\text{pts}\left\{ v_x = \frac{\Delta x}{\Delta t} \Rightarrow \Delta x = v_x \Delta t \Rightarrow x_f - \cancel{x_i}^{\,0} = v_x \Delta t \right.$$

$$2\text{pt}\left\{ x_f = (0.8\ \text{m}/\cancel{s})(1.96\ \cancel{\text{sec}}) = 1.568\ \text{m} \right.$$

$$\boxed{\text{range of Greco-projectile} = 1.568\ \text{m}}$$

(c 10pts) Determine Dr. Greco's velocity the instant he hits the water. Your answer should be a vector.

$$v_{x,f} = v_{x,i} = 0.8\ \text{m/s}$$

For $v_{y,f}$ we apply the momentum principle:

$$P_{fy} = P_{iy} + F_{net,y}\,\Delta t$$

$$\cancel{m} v_{fy} = \cancel{m} v_{iy} - \cancel{m} g\,\Delta t$$

−0.5
−1.5
−3.6
−8.0

$$v_{fy} = v_{iy} - g\,\Delta t = (4.5) - (9.8)(1.96)$$

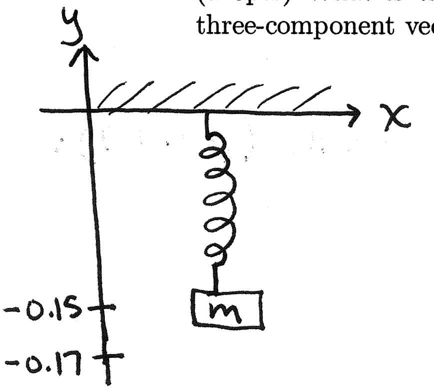
$$v_{fy} = 4.5 - 19.208 = -14.708\ \text{m/s}$$

$$\boxed{v_f = \langle 0.8, -14.708, 0 \rangle\ \text{m/s}}$$

Problem 4 (25 Points)

A block of 0.03 kg is attached to a vertically-hanging spring with a spring stiffness of 12 N/m and a relaxed length of 0.15 m. You grab the block and hold it motionless such that the spring has a length of 0.17 m. You then remove your hand. While working through the questions below be sure to include the gravitational force acting on the block.

(a 5pts) What is the net force on the mass just after you release it? Express your final answer as a three-component vector. Include a small sketch of the system showing your choice of coordinate axes.



$$\vec{F}_{net} = \vec{F}_s + \vec{F}_g = -K\Delta\vec{L} - mg\,\hat{y} \quad \Big\} \text{ 2pts}$$

$$= \langle 0, -K(L-L_0) - mg, 0\rangle$$

$$= \langle 0, (-12)(-0.17-(-0.15)) - (0.03)(9.8), 0\rangle$$

$$= \langle 0, (-12)(-0.02) - 0.294, 0\rangle$$

$$= \langle 0, 0.24 - 0.294, 0\rangle \quad \Big\} \text{ 3pts}$$

$$\boxed{\vec{F}_{net} = \langle 0, -0.054, 0\rangle \text{ N}}$$

(b 5pts) Determine the vector momentum of the block 0.02 seconds after you release it from rest. You can assume that this time interval is sufficiently short such that only one iteration is necessary.

$$\vec{p}_f = \cancel{\vec{p}_i}^{\,0} + \vec{F}_{net}\,\Delta t \quad \text{2pts}$$

$$\vec{p}_f = \langle 0, -0.054, 0\rangle(0.02) \quad \Big\} \text{ 3pts}$$

$$\boxed{\vec{p}_f = \langle 0, -0.00108, 0\rangle \text{ kg m/s}}$$

(c 10pts) Determine the vector position of the block 0.02 seconds after you release it from rest.

$$\vec{p} = m\vec{v} \Rightarrow \vec{v} = \frac{\vec{p}}{m} = \frac{\langle 0, -0.00108, 0\rangle}{0.03} = \langle 0, -0.036, 0\rangle \text{ m/s}$$

Since it's a one-dimensional problem, we only use y-direction.

$$V_y = \frac{\Delta y}{\Delta t} = \frac{y_f - y_i}{\Delta t}$$

y_i is where you let go of the block, at the stretched length (-0.17):

$$V_y = \frac{y_f - y_i}{\Delta t}$$

$$-0.036 = \frac{y_f - (-0.17)}{0.02}$$

$$-0.036 = \frac{y_f + 0.17}{0.02}$$

$$y_f + 0.17 = (-0.036)(0.02)$$

$$y_f = -0.17 - 7.2\times10^{-4}$$

$$y_f = -0.17072 \text{ m}$$

-0.5
-1.5
-3.0
-8.0

Vector position at $t = 0.02$ sec:

$$\boxed{\vec{r}_f = \langle 0, -0.17072, 0\rangle \text{ m}}$$

(d 5pts) Using your result from part (c) determine the vector momentum of the block 0.04 seconds after release.

Position at $t = 0.02$ sec $\Rightarrow$ $\vec{r}_i = \langle 0, -0.17072, 0 \rangle$ m

(from part c) 1pt

Force at $t = 0.02$ sec:

$$\vec{F}_i = -k(L_i - L_0) - mg\,\hat{y} =$$

$$= (-12)(-0.17072 - (-0.15)) - (0.03)(9.8)\,\hat{y}$$

$$= 0.24864 - 0.294\,\hat{y} = -0.04536\text{N}\,\hat{y}$$

$$\vec{F}_i = \langle 0, -0.04536, 0 \rangle \text{ N}$$

2pts

Momentum principle: $\vec{p}_f = \vec{p}_i + \vec{F}_{net}\,\Delta t$

1pt

$\vec{p}_f \Rightarrow$ momentum at $t = 0.04$ sec (what we want)

$\vec{p}_i \Rightarrow$ momentum at $t = 0.02$ sec (from part b)

$\vec{F}_{net} \Rightarrow$ force at $t = 0.02$ sec (calculated above)

$t_f \Rightarrow 0.04$ sec and $t_i \Rightarrow 0.02$ sec

So:

$$\vec{p}_f = \langle 0, -0.00108, 0 \rangle + \langle 0, -0.04536, 0 \rangle (0.04 - 0.02)$$

$$= \langle 0, -0.00108, 0 \rangle + \langle 0, -0.04536, 0 \rangle (0.02)$$

$$= \langle 0, -0.00108, 0 \rangle + \langle 0, -9.072 \times 10^{-4}, 0 \rangle$$

1pt

$$\boxed{\vec{p}_f = \langle 0, -0.0019872, 0 \rangle \text{ kg m/s}}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

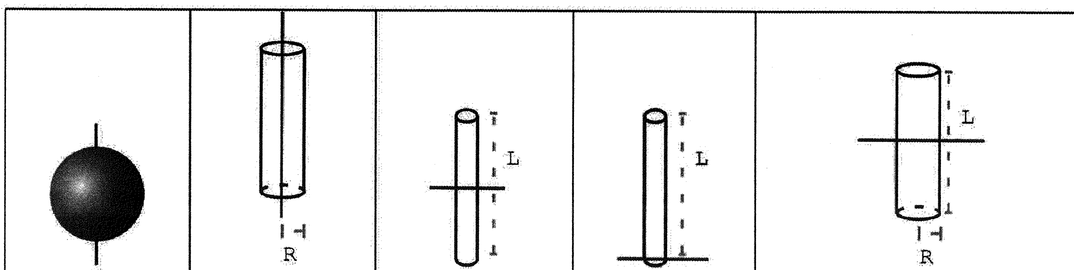
$$E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1, 2, 3\ldots$$

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

Moment of intertia for rotation about indicated axis

The cross product

$$\vec{A} \times \vec{B} = \langle A_yB_z - A_zB_y, A_zB_x - A_xB_z, A_xB_y - A_yB_x \rangle$$



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

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}