PHYS 2211 Test 1
Spring 2011

Name(print)____

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 don't want us to read!
- Make explanations correct but brief. Don't 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't 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

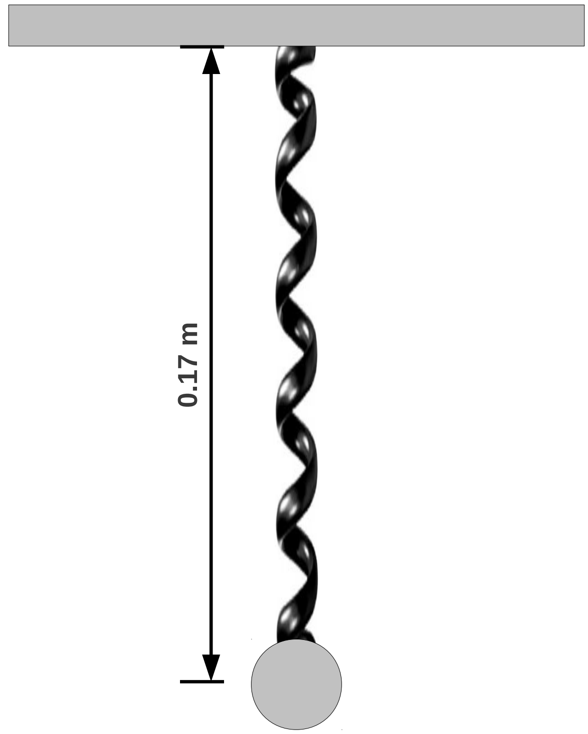
PHYS 2211

Do not write on this page!

Problem	Score	Grader
Problem 1 (25 pts)		
Problem 2 (30 pts)		
Problem 3 (25 pts)		
Problem 4 (20 pts)		

Problem 1 (25 Points)

A mass 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 pull the mass downwards, so that the spring's length is 0.17m. Then you release it so that when it leaves your hand it has zero velocity.



The First Time Step

(a 5pts) What is the net force on the mass the instant after you release it? Remember to express your answer as a vector.

(b 5pts) What is the new velocity of the mass 0.02 seconds after you release it from rest? Remember to express your answer as a vector. You may assume the net force is constant over this relatively short time period.

(c 5pts) What is the new position of the mass 0.02 seconds after you release it from rest? Remember to express your answer as a vector. You may assume the net force is constant over this relatively short time period.

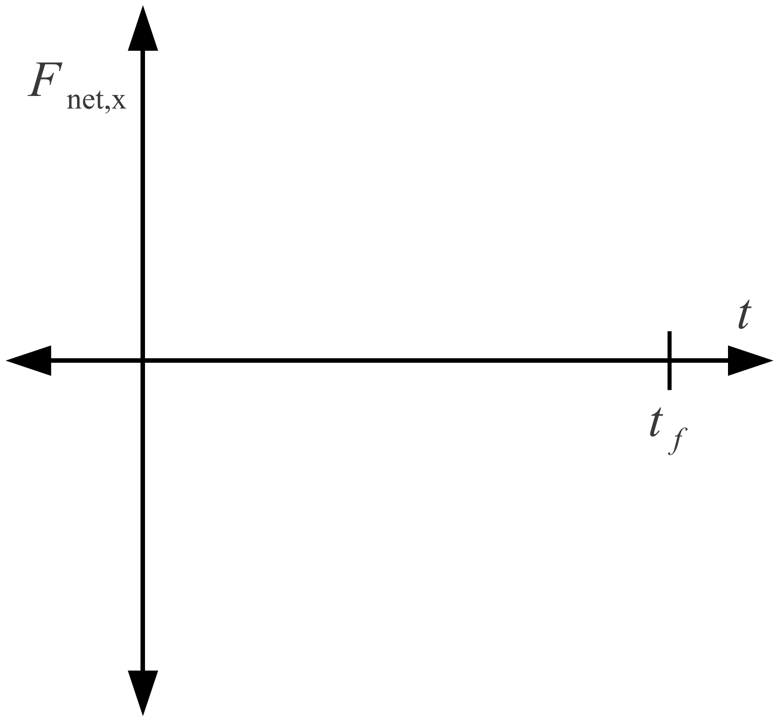
The Second Time Step

(d 10pts) What is the new velocity of the mass, a second time step later (i.e. at 0.04 seconds) after you release it from rest? Remember to express your answer as a vector. You may assume the net force is constant over the relatively short time period 0.02 to 0.04 seconds.

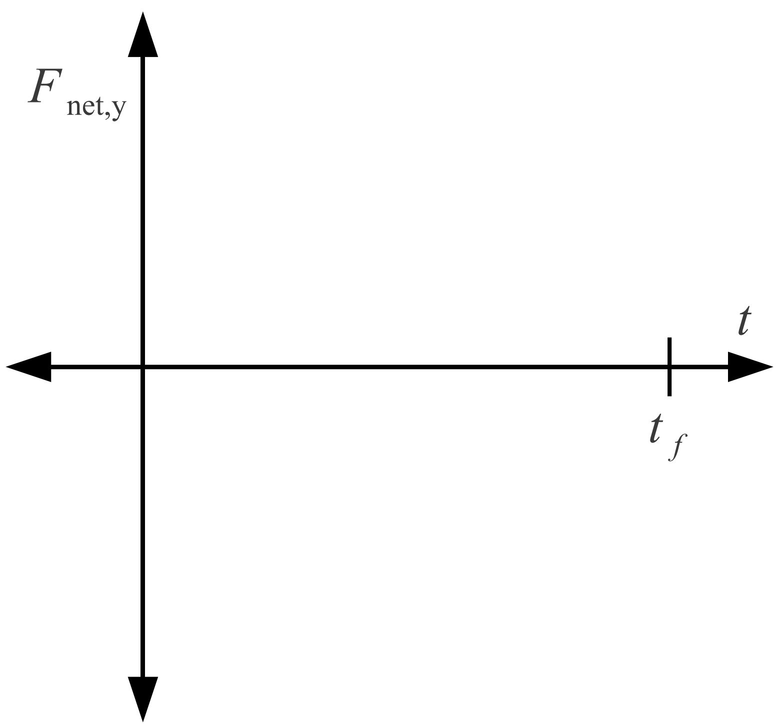
Problem 2 (30 Points)

Consider a ball of mass m that is kicked such that it has and an initial velocity of $< v_{x,i}, v_{y,i}, 0 >$ m/s, where $v_{x,i} > 0$ and $v_{y,i} > 0$ are both positive. The initial position of the ball is $< 0, 0, 0 >$ m and the only force acting on the ball is gravity (the weight) In the questions below, you will be asked to plot various components of the force, velocity and position versus time. When doing this, consider a time interval from the instant just after the ball is kicked ($t = 0$) until the instant before the ball reaches the ground ($t = t_f$).

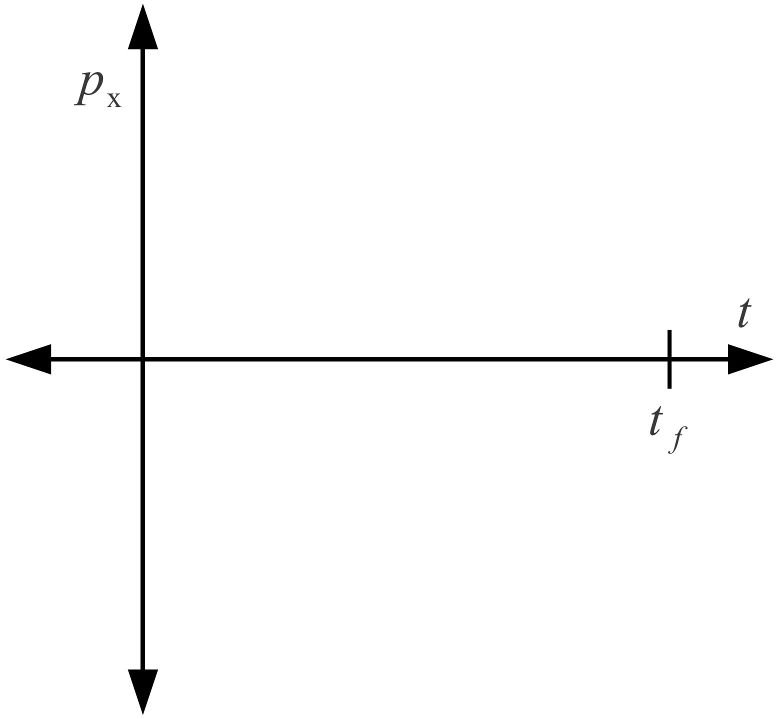
(a 5pts) Plot the x-component of the force $F_{net,x}$ versus time.



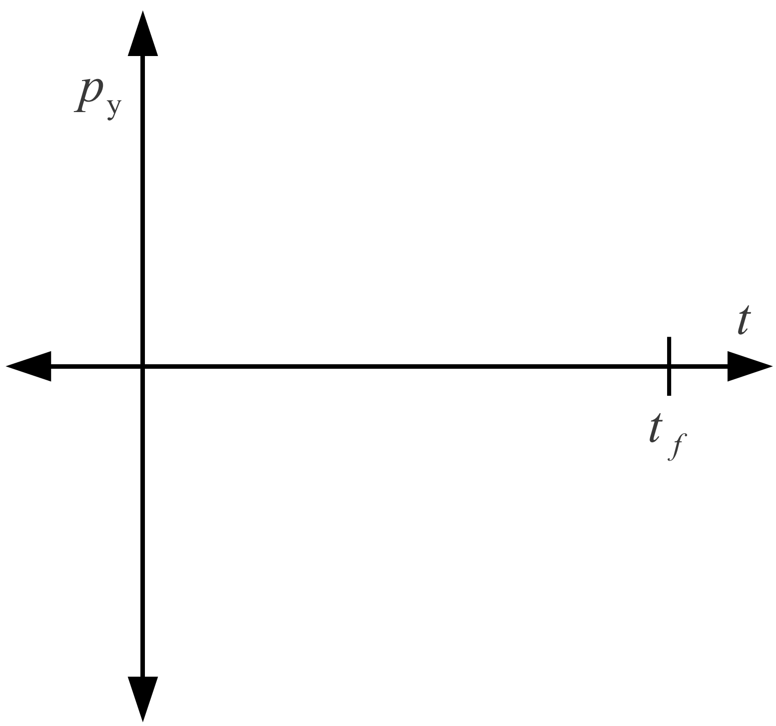
(b 5pts) Plot the y-component of the force $F_{net,y}$ versus time.



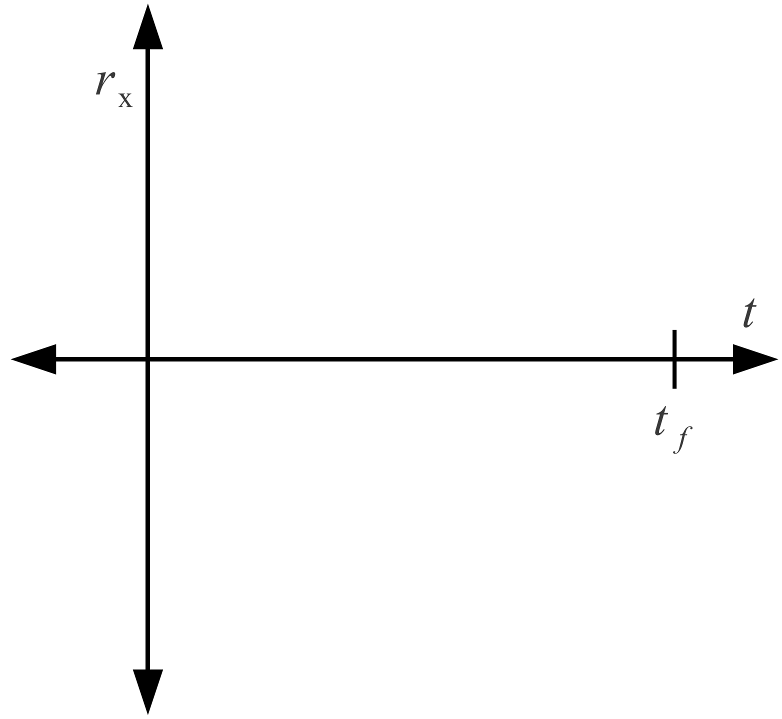
(c 5pts) Plot the x-component of the momentum p_x versus time.



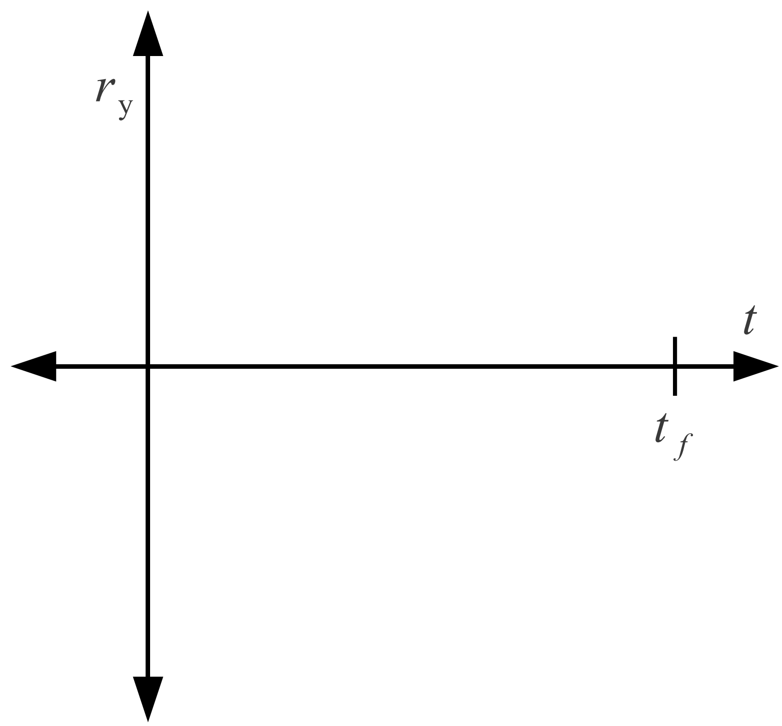
(d 5pts) Plot the y-component of the momentum p_y versus time.



(e 5pts) Plot the x-component of the position r_x versus time.

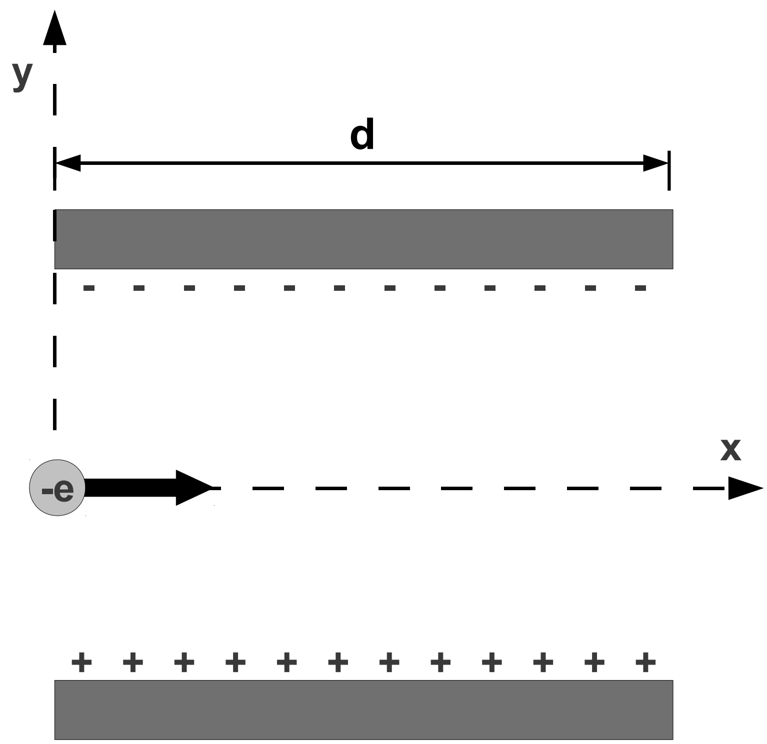


(f 5pts) Plot the y-component of the position r_y versus time.



Problem 3 (25 Points)

An electron of mass m_e enters a set of charged parallel plates with an initial velocity $\vec{v}_0 =< v_{ix}, 0, 0 >$. The electron experiences a constant force $\vec{F} =< 0, -F, 0 >$ in the negative y direction. The gravitational force on the electron is small compared to this force and can be neglected. The length of the plates is d. You may assume that the electron is moving, at all times, with a speed much less than c.



(a 5pts) How long does it take for the electron to reach the end of the parallel plates (i. e. at $x = d$)?

(b 10pts) What is the electron's final velocity when it reaches the end of the parallel plates (i. e. at $x = d$)? Remember to express your answer as a vector.

(c 10pts) What is the electron's final position relative to its starting position (i. e. at $r_0 =< 0, 0, 0 >$) when it reaches the end of the parallel plates (i. e. at $x = d$)? Remember to express your answer as a vector.

Problem 4 (20 Points)

Recall that, in last week's lab, you studied the motion of a fan cart, and you wrote a computer model (VPython script) to predict a fancart's motion. The script given below, which is nearly identical to your computer model from lab, 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.

```
#************BEGIN COMPUTER MODEL OF FANCART*******************
from __future__ import division
from visual import *
track = box(pos = vector(0, -.05, 0), size = (2.0, 0.05, .10), color = color.white)
cart = box(pos=vector(0.081,0,0), size=(.1,.04,.06), color=color.green)
mcart = .2395
vcart = vector(.375, .368, 0)
pcart = mcart*vcart
print 'cart momentum =', pcart
deltat = 0.01
t = 0
Fair = vector(-0.062, 0, 0)
while t < 5.01:
    rate(100)
```

(a 12pts) Add statements **here** to update the momentum and the position of the fancart.

```
    t = t + deltat
print 'after the loop'
print 'final position is', cart.pos
#************ END COMPUTER MODEL OF FANCART*******************
```

This problem continues on the next page.

Refer to the code above to answer the following four questions:

(b 2pts) What is the initial position of the fancart? (Answer should be a vector with units.)

(c 2pts) What is the initial momentum of the fancart? (Answer should be a vector with units.)

(d 2pts) What is the net force on the fancart? (Answer should be a vector with units.)

(e 2pts) The animation from the computer model, as written above, shows motion of a fancart that is not typically observed for fancarts in lab experiments. (Hint: at the end of last week's fancart lab, you modified your computer model so that your animation showed the same untypical behavior.) Identify the source of this untypical behavior in the code and state briefly how you would change the model so that the animation of fancart motion would look like typical fancart lab observations.

This page is for extra work, if needed.

Things you must know:

Definition of average velocity
Definition of momentum
Definitions of particle energy, kinetic energy, and work

The Momentum Principle
The Energy Principle
The Angular Momentum Principle

Vector Products:

$$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$$

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

Multiparticle systems:

$$\vec{r}_{cm} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2 + \ldots}{m_1 + m_2 + \ldots} \qquad \vec{P}_{tot} \approx M_{tot} \vec{v}_{cm}\ (v << c) \qquad K_{tot} = K_{trans} + K_{rel}$$

$$K_{rel} = K_{rot} + K_{vib} \qquad K_{trans} \approx \frac{1}{2} M_{tot} v_{cm}^2\ (v << c) \qquad I = m_1 r_{1\perp}^2 + m_2 r_{2\perp}^2 + \ldots$$

$$K_{rot} = \frac{L_{rot}^2}{2I} = \frac{1}{2} I \omega^2 \qquad \vec{\tau}_A = \vec{r}_A \times \vec{F}$$

$$\vec{L}_{trans,A} = \vec{r}_{cm,A} \times \vec{P}_{tot} \qquad \vec{L}_{rot} = I \vec{\omega} \qquad \vec{L}_A = \vec{L}_{trans,A} + \vec{L}_{rot}$$

Other physical quantities:

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

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

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

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

$\left|\vec{F}_{spring}\right| = k_s s$ opposite to the stretch $\qquad U_{spring} = \frac{1}{2} k_s s^2$ for ideal spring

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

$E_N = -\dfrac{13.6\text{eV}}{N^2}$ where $N = 1, 2, 3 \ldots$ (Hydrogen atom energy levels)

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

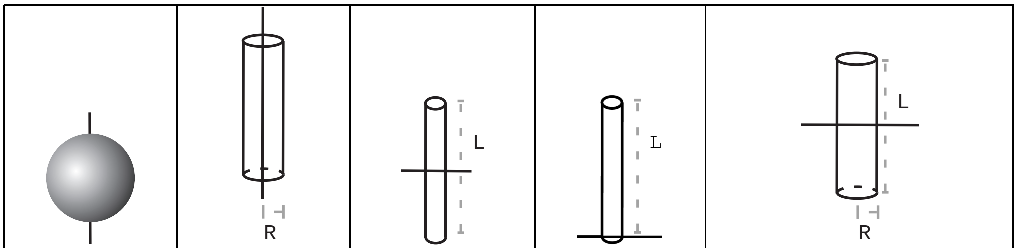
$\dfrac{d\vec{p}}{dt} = \dfrac{d|\vec{p}|}{dt}\hat{p} + |\vec{p}|\dfrac{d\hat{p}}{dt}$ where $\vec{F}_{\|} = \dfrac{d|\vec{p}|}{dt}\hat{p}$ and $\vec{F}_{\perp} = |\vec{p}|\dfrac{d\hat{p}}{dt} = |\vec{p}|\dfrac{|\vec{v}|}{R}\hat{n}$ and R is the radius of the kissing circle

$$\omega = \frac{2\pi}{T} \qquad x = A\cos\omega t \qquad \omega = \sqrt{\frac{k_s}{m}}$$

$Y = \dfrac{F/A}{\Delta L/L}$ (macro) $\qquad Y = \dfrac{k_{si}}{d}$ (micro) $\qquad$ speed of sound $v = d\sqrt{\dfrac{k_{si}}{m_a}}$

$\hat{f} = \langle \cos\theta_x, \cos\theta_y, \cos\theta_z \rangle$ unit vector from angles

Moment of intertia for rotation about indicated axis



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

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

$$\Delta S = \frac{Q}{T} \text{ (small } Q\text{)} \qquad \text{prob}(E) \propto \Omega\,(E)\, e^{-\frac{E}{kT}}$$

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}