

# PHYS 2211 Test 2

## Spring 2012

Name(print)\_\_\_\_\_ Lab Section\_\_\_\_\_

Lab section by day and time: Greco(M), Schatz(K,N)			
Day	12:05pm-2:55pm	3:05pm-5:55pm	6:05pm-8:55pm
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.:**  $\frac{a \cdot b}{c \cdot d} = \frac{(8 \times 10^{-3})(5 \times 10^6)}{(2 \times 10^{-5})(4 \times 10^4)} = 5 \times 10^4$
- 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 (38 pts)		
Problem 4 (12 pts)		

### Problem 1 (25 Points)

An electron interacts with a negatively charged molecule with net charge  $-4e$ . Below is an incomplete VPython program to calculate the position of the electron moving near the molecule. Fill in the missing VPython statements below to update the position of the electron. You may assume that the molecule is massive enough that it will remain motionless. The electron and molecule are far from any other objects and we will assume that they only interact through the electric force.

```
from visual import *
# Objects
molecule = sphere(pos=vector(0,0,0),color=color.black,radius=5e-6)
electron = sphere(pos=vector(1e-10,6e-10,0),color=color.gray,radius=5e-8)

# Charge and Mass
k = 9e9 %One over four pi epsilon
e = 1.6e-19 %Charge of a proton
melectron = 9e-31 %Mass of an electron

# Initial values
pelectron = melectron*vector(2e4,-7e4,0)
deltat = 1e-3
t = 0
while t < 100
# (a 15pts) Update the position of the electron
```

```
# (b 10pts) Calculate the components of the net force on the electron.
#           You may need to add a line or two of code to part (a).
```

```
    Fnet_tangent =
```

```
    Fnet_perpendicular =
```

```
    t = t + deltat
```

Problem 2 (25 Points)

The US nickel (5 cents) has a mass of 5.0 g, a diameter of 21.21 mm, and an average thickness of 1.95 mm. For this problem we will assume that the nickel is made of pure nickel, with a density of  $8908 \frac{\text{kg}}{\text{m}^3}$  and its atomic weight is  $58.69 \frac{\text{g}}{\text{mol}}$ . The speed of sound in nickel is  $4900 \frac{\text{m}}{\text{s}}$ .

(a 5pts) What is the diameter of a single nickel atom?

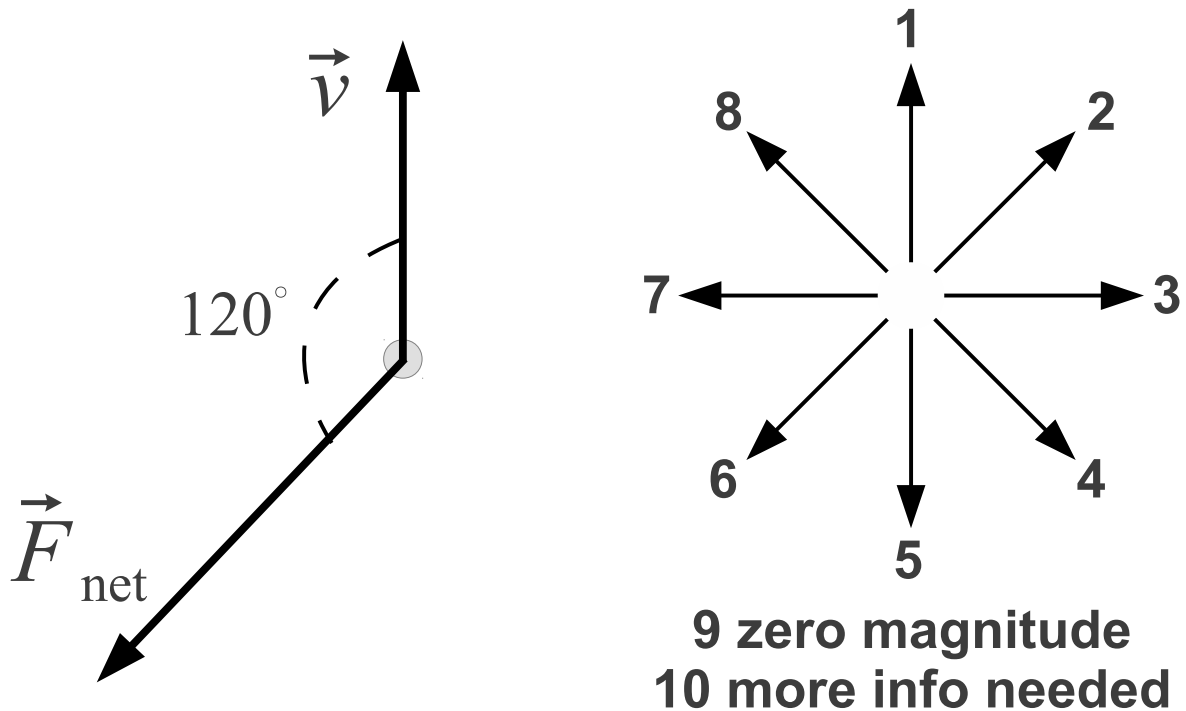
(b 5pts) How many atoms are on the face of a nickel?

(c 15pts) An elephant of mass 10900 kg stands on single, flat nickel. Determine how much the nickel is compressed.

Problem 3 (38 Points)

Part 1: An object of mass  $m = 5$  kg has velocity  $\vec{v}$ , and a net force  $\vec{F}_{net}$  acting on it at time  $t$  in figure below. At this instant of time,  $|\vec{F}_{net}| = 100$  N and  $\theta = 120$  degrees.

Using the numbered direction arrows shown, indicate (by number) which arrow *best represents* the direction of the quantities listed below. If the quantity has zero magnitude or if more information is needed to determine the direction, indicate using the corresponding number listed below.



- (a 1pt)  $\vec{p}$ , the object's momentum. \_\_\_\_\_
- (b 1pt)  $(\vec{F}_{net})_{\parallel}$ , the component of  $\vec{F}_{net}$  that is parallel to the object's velocity. \_\_\_\_\_
- (c 1pt)  $(\vec{F}_{net})_{\perp}$ , the component of  $\vec{F}_{net}$  that is perpendicular to the object's velocity. \_\_\_\_\_
- (d 1pt)  $\vec{F}_{gravity}$ , the force of gravity acting on the object. \_\_\_\_\_
- (f 1pt)  $\vec{a}$ , the object's acceleration. \_\_\_\_\_
- (g 1pt)  $\frac{d\vec{p}}{dt}$ , the time rate of change of the object's momentum. \_\_\_\_\_
- (h 1pt)  $(\frac{d\vec{p}}{dt})_{\parallel}$ , the component of  $\frac{d\vec{p}}{dt}$  that is parallel to the ball's velocity. \_\_\_\_\_
- (i 1pt)  $(\frac{d\vec{p}}{dt})_{\perp}$ , the component of  $\frac{d\vec{p}}{dt}$  that is perpendicular to the ball's velocity. \_\_\_\_\_

Referring to the object of mass  $m = 5$  kg at time  $t$  shown in figure on the previous page, answer the following questions. At this instant of time,  $|\vec{F}_{net}| = 100$  N and  $\theta = 120$  degrees. Note that the directions "right" and "left" correspond to your perspective, as you look at the page.

**YOU MUST SHOW UNITS FOR ALL NUMERICAL RESPONSES.**

(j 1pt) (CIRCLE ONE) At time  $t$ , the object's speed is:

- increasing.
- decreasing.
- constant.
- unable to be determined with the given information.

(k 1pt) (CIRCLE ONE) At time  $t$ , the object is turning:

- to the left.
- to the right.
- neither left or right. It is moving in a straight line.
- in a way that can't be determined with the given information.

(l 1pt) Find  $|(\vec{F}_{net})_{\parallel}|$ , the magnitude of the component of  $\vec{F}_{net}$  that is parallel to the ball's velocity.

(m 1pt) Find  $|(\vec{F}_{net})_{\perp}|$ , the magnitude of the component of  $\vec{F}_{net}$  that is perpendicular to the ball's velocity.

(n 1pt)  $|\frac{d\vec{p}}{dt}|$ , the magnitude of the time rate of change of momentum.

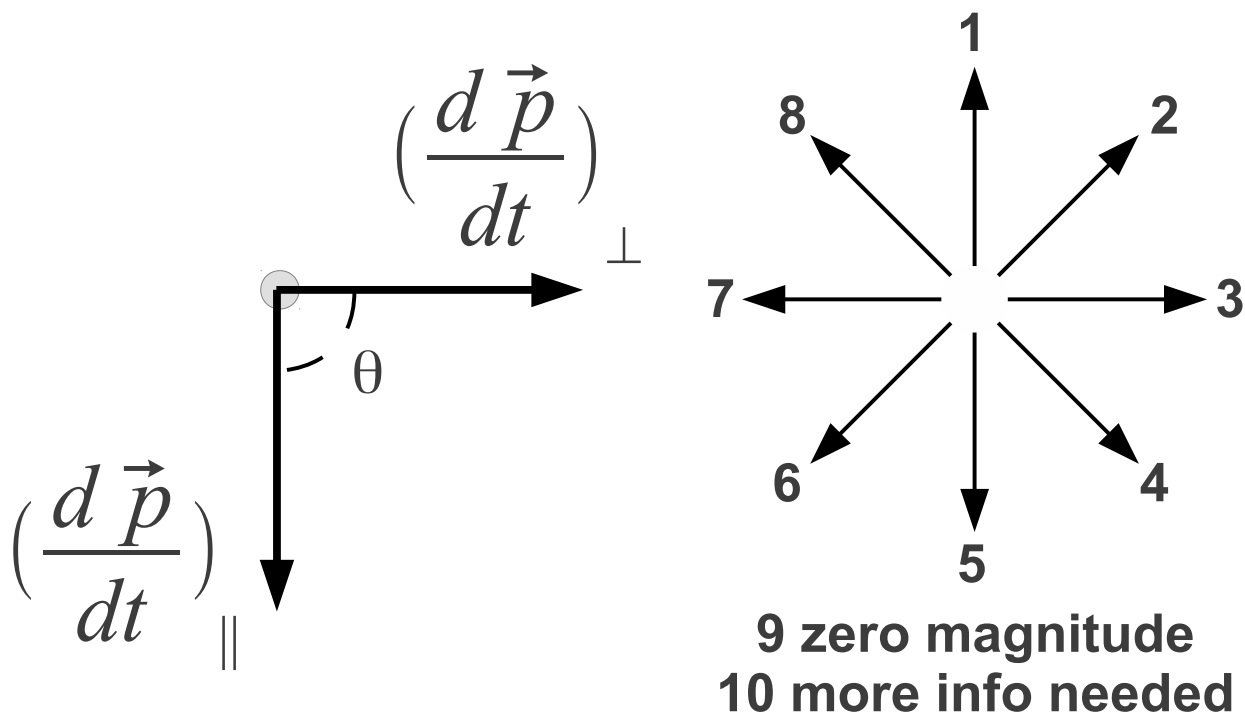
(n 1pt)  $|(\frac{d\vec{p}}{dt})_{\parallel}|$ , the magnitude of the component of  $\frac{d\vec{p}}{dt}$  that is parallel to the ball's velocity.

(o 1pt)  $|(\frac{d\vec{p}}{dt})_{\perp}|$ , the magnitude of the component of  $\frac{d\vec{p}}{dt}$  that is perpendicular to the ball's velocity.

(p 1pt)  $|\vec{a}|$ , the magnitude of the acceleration.

Part 2:  $(\frac{d\vec{p}}{dt})_{\parallel}$  and  $(\frac{d\vec{p}}{dt})_{\perp}$  for an object of mass  $m = 10$  kg are shown at time  $t$  in the figure below. At this instant of time,  $|(\frac{d\vec{p}}{dt})_{\parallel}| = 40$  kg m/s<sup>2</sup>,  $|(\frac{d\vec{p}}{dt})_{\perp}| = 42$  kg m/s<sup>2</sup>, and  $\theta = 90$  degrees.

Using the numbered direction arrows shown, indicate (by number) which arrow *best represents* the direction of the quantities listed below. If the quantity has zero magnitude or if more information is needed to determine the direction, indicate using the corresponding number listed below.



(a 1pt)  $\vec{p}$ , the object's momentum. \_\_\_\_\_

(b 1pt)  $(\vec{F}_{net})_{\parallel}$ , the component of  $\vec{F}_{net}$  that is parallel to the object's velocity. \_\_\_\_\_

(c 1pt)  $(\vec{F}_{net})_{\perp}$ , the component of  $\vec{F}_{net}$  that is perpendicular to the object's velocity. \_\_\_\_\_

(d 1pt)  $\vec{F}_{gravity}$ , the force of gravity acting on the object. \_\_\_\_\_

(f 1pt)  $\vec{a}$ , the object's acceleration. \_\_\_\_\_

(g 1pt)  $\frac{d\vec{p}}{dt}$ , the time rate of change of the object's momentum. \_\_\_\_\_

(h 1pt)  $\vec{v}$ , the object's velocity \_\_\_\_\_

Referring to the object of mass  $m = 10$  kg at time  $t$  shown in the figure on the previous page, answer the following questions. At this instant of time,  $|(\frac{d\vec{p}}{dt})_{\parallel}| = 40$  kg m/s<sup>2</sup>,  $|(\frac{d\vec{p}}{dt})_{\perp}| = 42$  kg m/s<sup>2</sup>, and  $\theta = 90$  degrees. Note that the directions "right" and "left" correspond to your perspective, as you look at the page.

**YOU MUST SHOW UNITS FOR ALL NUMERICAL RESPONSES.**

(i 1pt) (CIRCLE ONE) At time  $t$ , the object's speed is:

- increasing.
- decreasing.
- constant.
- unable to be determined with the given information.

(j 1pt) (CIRCLE ONE) At time  $t$ , the object is turning:

- to the left.
- to the right.
- neither left or right. It is moving in a straight line.
- in a way that can't be determined with the given information.

(l 1pt) Find  $|(\vec{F}_{net})|$ , the magnitude of the net force.

(m 1pt) Find  $|(\vec{F}_{net})_{\parallel}|$ .

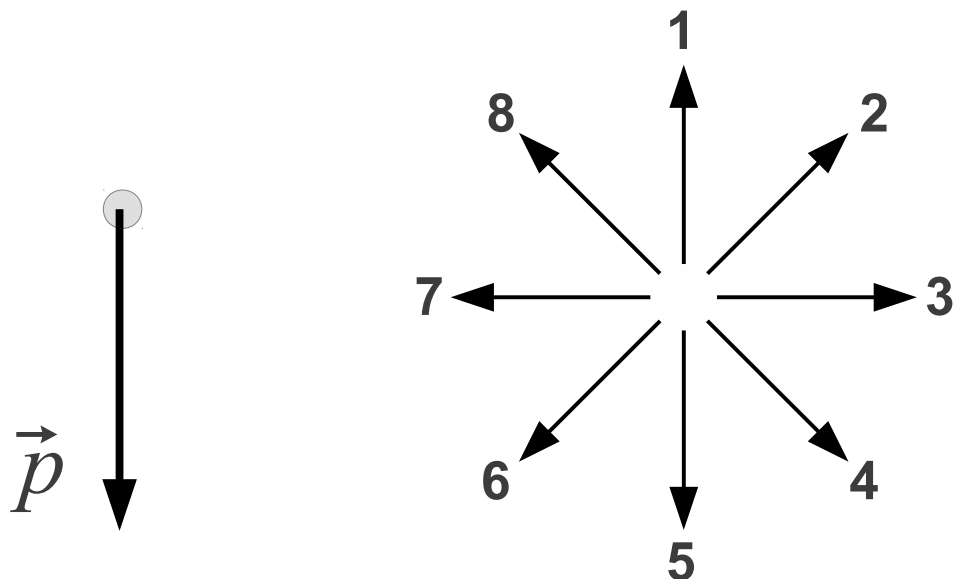
(n 1pt) Find  $|(\vec{F}_{net})_{\perp}|$ .

(o 1pt) Find  $|\vec{a}|$ , the magnitude of the acceleration.



Part 3: The momentum  $\vec{p}$  of an object is shown at time  $t$  in the figure below.

Using the numbered direction arrows shown, indicate (by number) which arrow *best represents* the direction of the quantities listed below. If the quantity has zero magnitude or if more information is needed to determine the direction, indicate using the corresponding number listed below. Note that the directions "right" and "left" correspond to your perspective, as you look at the page.



**9 zero magnitude**  
**10 more info needed**

(p 1pt) If the object is slowing down and turning right, what is the direction of  $\vec{F}_{net}$ ? \_\_\_\_\_

(q 1pt) If the object is speeding up and turning right, what is the direction of  $\vec{a}$  (the acceleration)? \_\_\_\_\_

(r 1pt) If the object is slowing down and turning left, what is the direction of  $\frac{d\vec{p}}{dt}$ ? \_\_\_\_\_

(s 1pt) If the object is slowing down and turning right, what is the direction of  $\vec{v}$  (the velocity)? \_\_\_\_\_

(t 1pt) If the object is slowing down and moving in straight line, what is the direction of  $\vec{v}$ ? \_\_\_\_\_

(u 1pt) If the object is speeding up and moving in straight line, what is the direction of  $\frac{d\vec{p}}{dt}$ ? \_\_\_\_\_

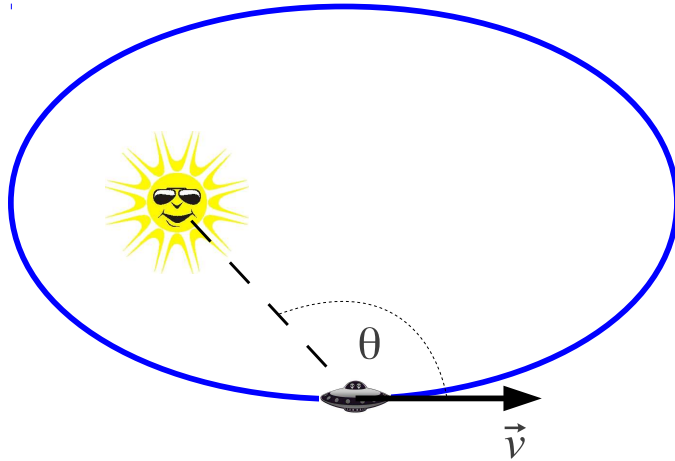
(v 1pt) If the object is moving at constant speed and in straight line, what is the direction of  $\vec{a}$ ? \_\_\_\_\_

(w 1pt) If the object is moving at constant speed and turning left, what is the direction of  $\vec{F}_{net}$ ? \_\_\_\_\_

(x 1pt) If the object is moving at constant speed and turning right, what is the direction of  $\vec{F}_{net}$ ? \_\_\_\_\_

Problem 4 (12 Points)

A planet of mass  $6e24$  kg orbits a star of mass  $2e30$  kg. At the instant shown in the figure below, the star is located at  $\langle -5.00e10, 0, 0 \rangle$  m, and the planet is located at  $\langle 1.41e10, -5.71e10, 0 \rangle$  m, moving with a velocity of  $\langle 3.95e4, 0, 0 \rangle$  m/s. The gravitational attraction of the star is the only significant force on the planet. The line passing through the centers of both the planet and star is shown in the figure; the angle  $\theta$  between that line and the planet's velocity is 138 degrees.



(a 6pts) Calculate the gravitational force of the star on the planet. Express your answer as a three-component vector.

(b 3pts) Calculate  $(\frac{d\vec{p}}{dt})_{\parallel}$  for the planet. Express your answer as a three-component vector.

(c 3pts) Calculate  $(\frac{d\vec{p}}{dt})_{\perp}$  for the planet. Express your answer as a three-component vector.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$E^2 - (pc)^2 = (mc^2)^2$$

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

$$U_{grav} = -G\frac{m_1m_2}{|\vec{r}|}$$

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

$$U_{elec} = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{|\vec{r}|}$$

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

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

$$I = m_1r_{1\perp}^2 + m_2r_{2\perp}^2 + \dots$$

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

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

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

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

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





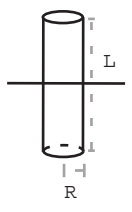
$$S \equiv k \ln \Omega$$

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

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

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

### Moment of inertia for rotation about indicated axis

 $I = \frac{2}{5}MR^2$	 $I = \frac{1}{2}MR^2$	 $I = \frac{1}{12}ML^2$	 $I = \frac{1}{3}ML^2$	 $I = \frac{1}{12}ML^2 + \frac{1}{4}MR^2$
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Constant	Symbol	Approximate Value
Speed of light	$c$	$3 \times 10^8$ m/s
Gravitational constant	$G$	$6.7 \times 10^{-11}$ N · m <sup>2</sup> /kg <sup>2</sup>
Approx. grav field near Earth's surface	$g$	9.8 N/kg
Electron mass	$m_e$	$9 \times 10^{-31}$ kg
Proton mass	$m_p$	$1.7 \times 10^{-27}$ kg
Neutron mass	$m_n$	$1.7 \times 10^{-27}$ kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	$9 \times 10^9$ N · m <sup>2</sup> /C <sup>2</sup>
Proton charge	$e$	$1.6 \times 10^{-19}$ C
Electron volt	1 eV	$1.6 \times 10^{-19}$ J
Avogadro's number	$N_A$	$6.02 \times 10^{23}$ atoms/mol
Plank's constant	$h$	$6.6 \times 10^{-34}$ joule · second
$\hbar = \frac{h}{2\pi}$	$\hbar$	$1.05 \times 10^{-34}$ joule · second
specific heat capacity of water	$C$	4.2 J/g/K
Boltzmann constant	$k$	$1.38 \times 10^{-23}$ J/K

milli	m	$1 \times 10^{-3}$
micro	$\mu$	$1 \times 10^{-6}$
nano	n	$1 \times 10^{-9}$
pico	p	$1 \times 10^{-12}$

kilo	K	$1 \times 10^3$
mega	M	$1 \times 10^6$
giga	G	$1 \times 10^9$
tera	T	$1 \times 10^{12}$