PHYS 2211 Test 1
Fall 2015

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

- Give standard SI units with your 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.

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.

F

$\vec{v}_F$

D

$\vec{v}_E$

$\vec{v}_D$

E

1
8   2
7   3
6   4
5

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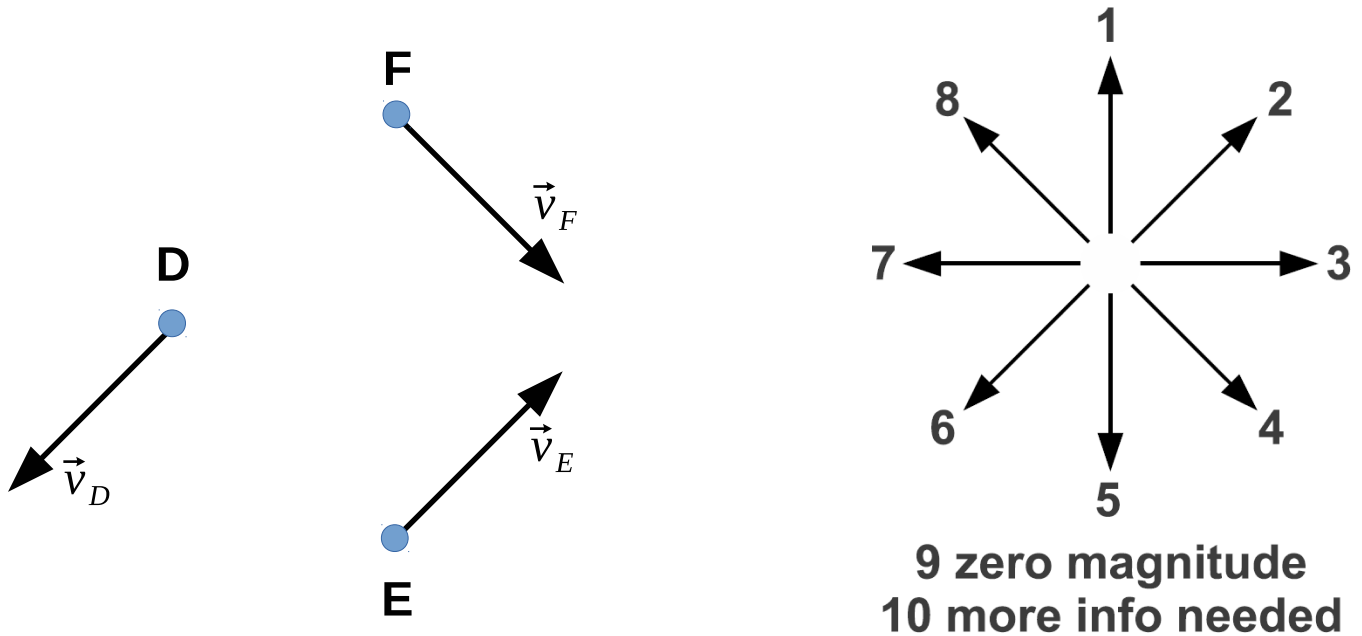
(a 10pts) Using the numbered direction arrows shown, indicate (by number) which direction arrow best represents the direction of the quantities listed below. If the quantity has zero magnitude or cannot be determined, indicate using the corresponding number listed below.

The position vector at location D _____

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

The change in velocity between location D and location F _____

The change in momentum between location D and location F _____

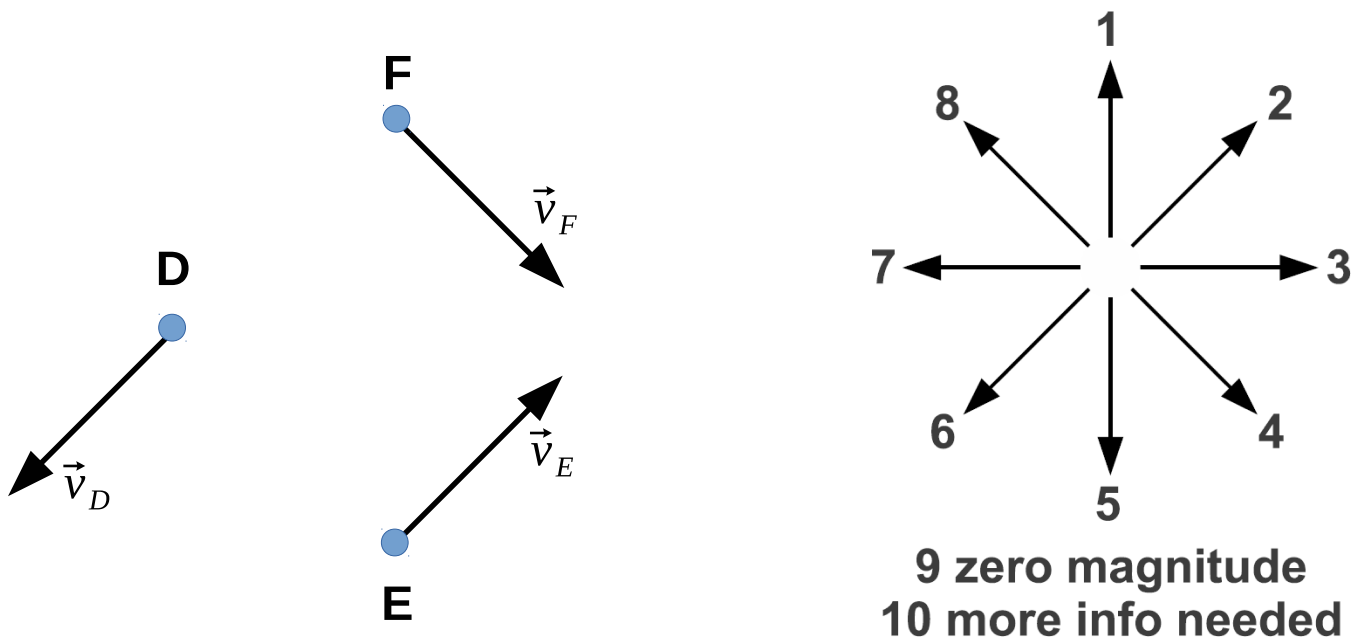The average net force between location D and location F _____

The position vector at location E _____

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

The change in velocity between location D and location E _____

The change in momentum between location D and location E _____

The average net force between location D and location E _____

(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 _____

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

The change in velocity between location E and location F _____

The change in momentum between location E and location F _____

The average net force between location E and location F _____

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

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

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

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

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

_____ 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
```

(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 $\vec{v}_{avg} \approx \vec{v}_f$.

```
    t = t + deltat
```

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

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

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

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

(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.
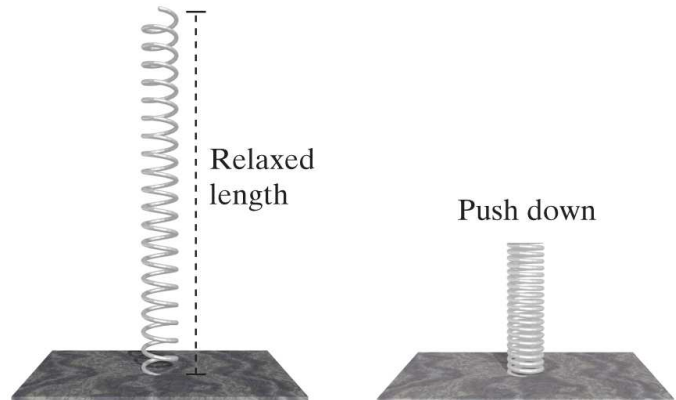
Problem 3 (25 Points)

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.

(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.

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.

Relaxed length

Push down

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

● electron

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.

● proton

(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.

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

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

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

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

This page is for extra work, if needed.

Things you must have memorized

The Momentum Principle	The Energy Principle	The Angular Momentum Principle
Definition of Momentum	Definition of Velocity	Definition of Angular Momentum
Definitions of angular velocity, particle energy, kinetic energy, and work		

Other potentially useful relationships and quantities

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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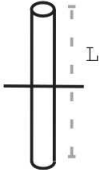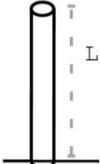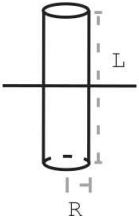
$$E_N = -\frac{13.6\text{eV}}{N^2} \text{ where } N = 1, 2, 3\dots$$

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

Moment of intertia for rotation about indicated axis

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

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

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	$\dfrac{1}{4\pi\epsilon_0}$	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 $= \dfrac{h}{2\pi}$	$\hbar$	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}