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.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^4$
- 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

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
oofpez =    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
```

```
    r = electron.pos - molecule.pos
    rmag = mag(r)
    rhat = r/rmag
    Fnet = oofpez * (-e) * (-4*e) /rmag ** 2 * rhat
    p-i = mag(pelectron)     # added for part (b)
    pelectron = pelectron + Fnet * deltat
    p_f = mag(pelectron)     # added for part (b)
    electron.pos = electron.pos + pelectron/melectron * deltat
```

```
# (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 = (p_f - p_i)/deltat * pelectron / p_f

   Fnet_perpendicular = Fnet - Fnet_tangent

   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?

$$d \approx V_{atom}^{1/3} = \left[\left(\frac{1}{D}\right) M \left(\frac{1}{N_A}\right)\right]^{1/3} = \left[\left(\frac{1}{8908\ \text{kg/m}^3}\right)\left(0.05869\ \text{kg/mol}\right)\left(\frac{1}{6.02\times10^{23}\ \text{atoms/mol}}\right)\right]^{1/3}$$

$$d \approx \boxed{2.22\times10^{-10}\ \text{m}}$$

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

$$A_{atom} \approx d^2 = 4.93\times10^{-20}\ \text{m}^2$$

$$A_{nickel} = \pi r^2 = \pi\left(\frac{21.21\times10^{-3}\ \text{m}}{2}\right)^2 = 3.53\times10^{-4}\ \text{m}^2$$

$$N = \frac{A_{nickel}}{A_{atom}} = \frac{3.53\times10^{-4}\ \text{m}^2}{4.93\times10^{-20}\ \text{m}^2} = \boxed{7.17\times10^{15}\ \text{atoms}}$$

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

The speed of sound is $v = d\sqrt{\frac{k_{si}}{m_a}} \Rightarrow k_{si} = \frac{v^2}{d^2} m_a$ where $m_a = \frac{0.05869\ \text{kg/mol}}{6.02\times10^{23}\ \text{atoms/mol}} = 9.75\times10^{-26}\ \text{kg}$

Since $Y = \frac{F/A}{\Delta L/L_0}$ (macro) and $Y = \frac{k_{si}}{d}$ (micro), we can write

$$\frac{F/A}{\Delta L/L_0} = \frac{k_{si}}{d}$$

Plugging in the expression for k_{si}: $\frac{F/A}{\Delta L/L_0} = \frac{v^2}{d^3} m_a$

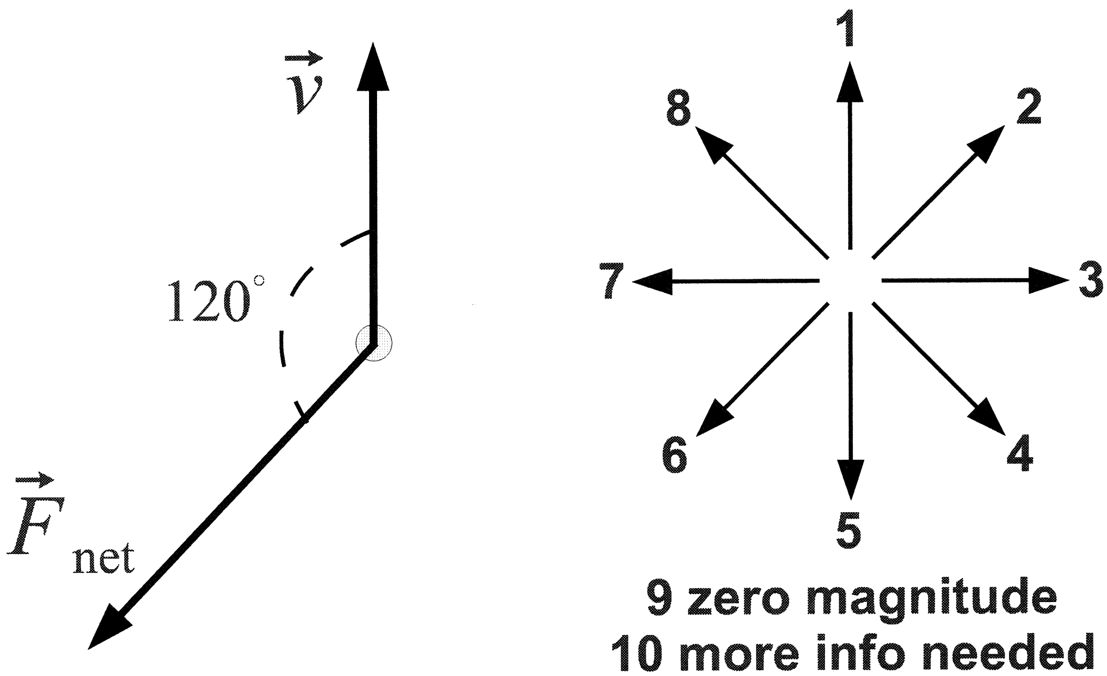
Solving for ΔL, we find $\Delta L = \frac{F L_0 d^3}{A v^2 m_a} = \frac{(10900\ \text{kg})(9.8\ \text{m/s}^2)(1.95\times10^{-3}\ \text{m})(2.22\times10^{-10}\ \text{m})^3}{(3.53\times10^{-4}\ \text{m}^2)(4900\ \text{m/s})^2(9.75\times10^{-26}\ \text{kg})}$

$$\Rightarrow \Delta L = \boxed{2.76\times10^{-6}\ \text{m}}$$

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. 1

(b 1pt) $(\vec{F}_{net})_{\parallel}$, the component of $\vec{F}_{net}$ that is parallel to the object's velocity. 5

(c 1pt) $(\vec{F}_{net})_{\perp}$, the component of $\vec{F}_{net}$ that is perpendicular to the object's velocity. 7

(d 1pt) $\vec{F}_{gravity}$, the force of gravity acting on the object. 10

(f 1pt) $\vec{a}$, the object's acceleration. 6

(g 1pt) $\frac{d\vec{p}}{dt}$, the time rate of change of the object's momentum. 6

(h 1pt) $(\frac{d\vec{p}}{dt})_{\parallel}$, the component of $\frac{d\vec{p}}{dt}$ that is parallel to the ball's velocity. 5

(i 1pt) $(\frac{d\vec{p}}{dt})_{\perp}$, the component of $\frac{d\vec{p}}{dt}$ that is perpendicular to the ball's velocity. 7

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

$$|(\vec{F}_{net})_{||}| = |(100N)\cos(120^\circ)| = \boxed{50\ N}$$

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

$$|(\vec{F}_{net})_{\perp}| = |(100N)\sin(120^\circ)| = \boxed{86.6\ N}$$

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

$$\left|\frac{d\vec{p}}{dt}\right| = |\vec{F}_{net}| \Rightarrow \left|\frac{d\vec{p}}{dt}\right| = \boxed{100\ N}$$

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

$$\left|\left(\frac{d\vec{p}}{dt}\right)_{||}\right| = |(\vec{F}_{net})_{||}| \Rightarrow \left|\left(\frac{d\vec{p}}{dt}\right)_{||}\right| = \boxed{50\ N}$$

(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.

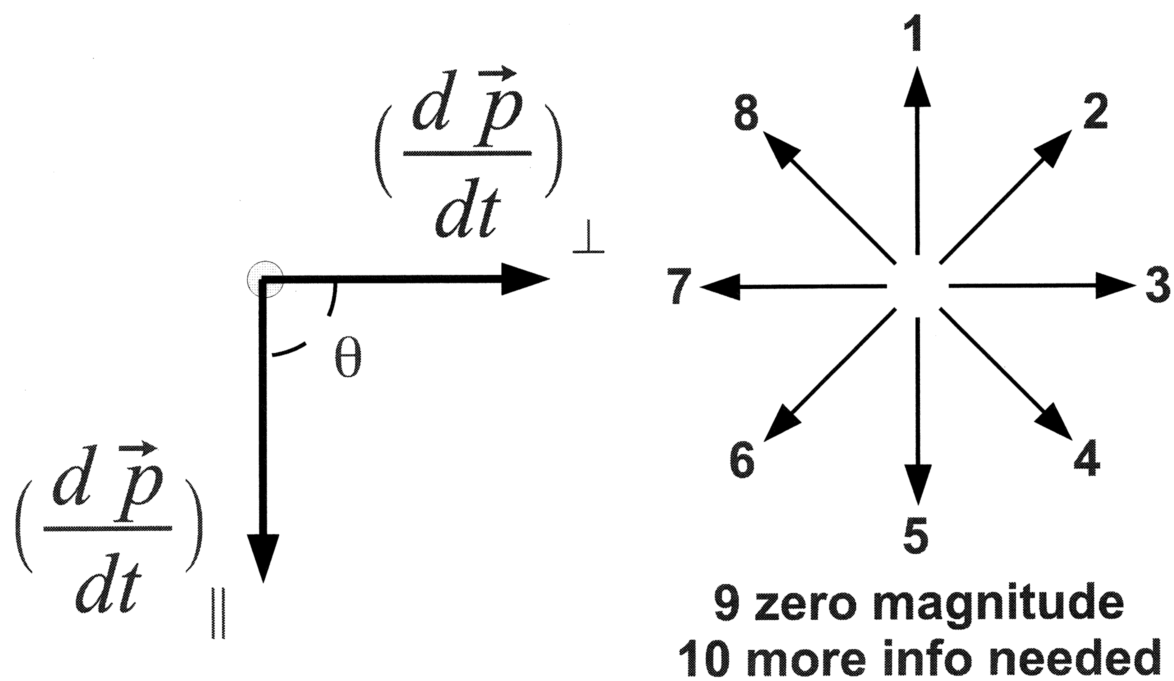
$$\left|\left(\frac{d\vec{p}}{dt}\right)_{\perp}\right| = |(\vec{F}_{net})_{\perp}| \Rightarrow \left|\left(\frac{d\vec{p}}{dt}\right)_{\perp}\right| = \boxed{86.6\ N}$$

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

$$\frac{d\vec{p}}{dt} = m\frac{d\vec{v}}{dt} = m\vec{a} \Rightarrow \vec{a} = \frac{1}{m}\frac{d\vec{p}}{dt} = \left(\frac{1}{5kg}\right)(100N) = \boxed{20\ m/s^2}$$

Part 2: $(\frac{d\vec{p}}{dt})_{\|}$ 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, $|(\frac{d\vec{p}}{dt})_{\|}| = 40$ kg m/s^2, $|(\frac{d\vec{p}}{dt})_{\perp}| = 42$ kg m/s^2, 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. 10

(b 1pt) $(\vec{F}_{net})_{\|}$, the component of $\vec{F}_{net}$ that is parallel to the object's velocity. 5

(c 1pt) $(\vec{F}_{net})_{\perp}$, the component of $\vec{F}_{net}$ that is perpendicular to the object's velocity. 3

(d 1pt) $\vec{F}_{gravity}$, the force of gravity acting on the object. 10

(f 1pt) $\vec{a}$, the object's acceleration. 4

(g 1pt) $\frac{d\vec{p}}{dt}$, the time rate of change of the object's momentum. 4

(h 1pt) $\vec{v}$, the object's velocity 10

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, $|(\frac{d\vec{p}}{dt})_{||}| = 40$ kg m/s^2, $|(\frac{d\vec{p}}{dt})_{\perp}| = 42$ kg m/s^2, 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.

$$|(\vec{F}_{net})| = \sqrt{(\vec{F}_{net})_{||}^2 + (\vec{F}_{net})_{\perp}^2} = \sqrt{\left(\frac{d\vec{p}}{dt}\right)_{||}^2 + \left(\frac{d\vec{p}}{dt}\right)_{\perp}^2} = \sqrt{(40\ \text{kg m/s}^2)^2 + (42\ \text{kg m/s}^2)^2}$$

$$|(\vec{F}_{net})| = \boxed{58\ N}$$

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

$$|(\vec{F}_{net})_{||}| = \left|\left(\frac{d\vec{p}}{dt}\right)_{||}\right| = \boxed{40\ N}$$

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

$$|(\vec{F}_{net})_{\perp}| = \left|\left(\frac{d\vec{p}}{dt}\right)_{\perp}\right| = \boxed{42\ N}$$

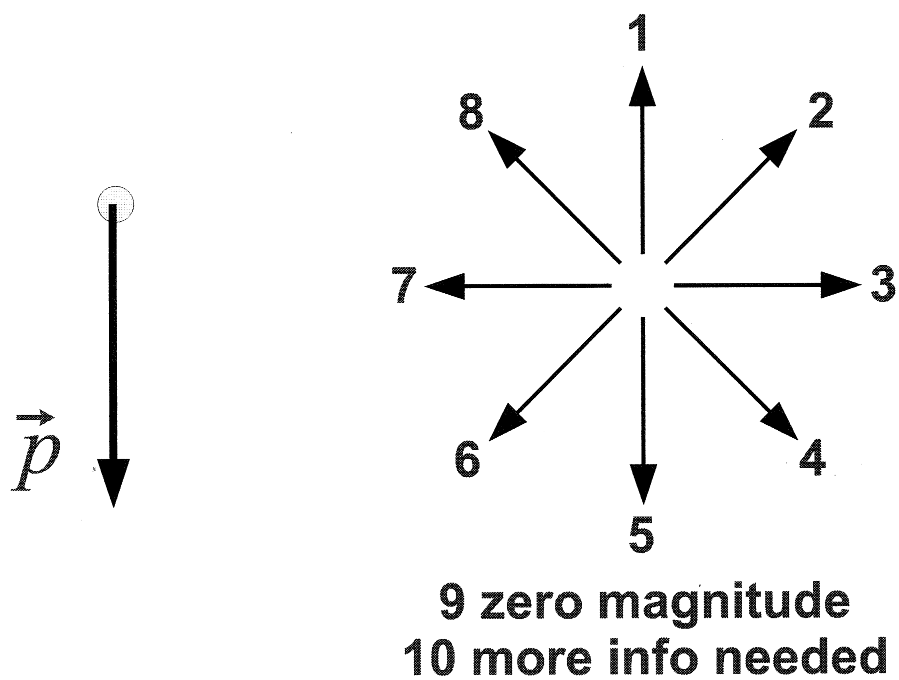
(o 1pt) Find $|\vec{a}|$, the magnitude of the acceleration.

$$|\vec{F}_{net}| = \left|\frac{d\vec{p}}{dt}\right| = m\left|\frac{d\vec{v}}{dt}\right| = m|\vec{a}|$$

$$\Rightarrow |\vec{a}| = \frac{1}{m}|\vec{F}_{net}| = \left(\frac{1}{10\text{kg}}\right)(58\ N) = \boxed{5.8\ m/s^2}$$

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.



(p 1pt) If the object is slowing down and turning right, what is the direction of $\vec{F}_{net}$? 2

(q 1pt) If the object is speeding up and turning right, what is the direction of $\vec{a}$ (the acceleration)? 4

(r 1pt) If the object is slowing down and turning left, what is the direction of $\frac{d\vec{p}}{dt}$? 8

(s 1pt) If the object is slowing down and turning right, what is the direction of $\vec{v}$ (the velocity)? 5

(t 1pt) If the object is slowing down and moving in straight line,
what is the direction of $\vec{v}$? 5

(u 1pt) If the object is speeding up and moving in straight line, what is the direction of $\frac{d\vec{p}}{dt}$? 5

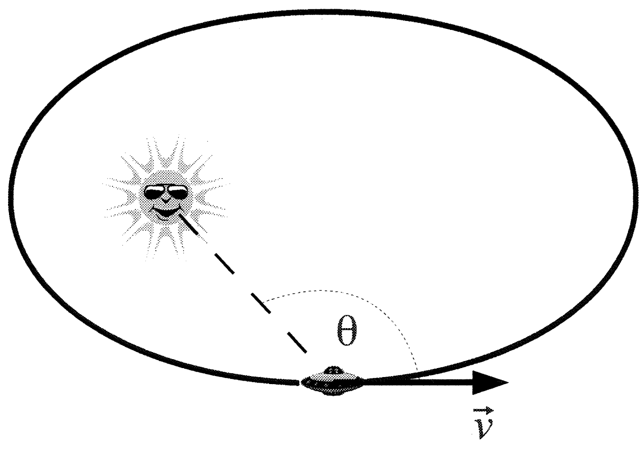
(v 1pt) If the object is moving at constant speed and in straight line, what is the direction of $\vec{a}$? 9

(w 1pt) If the object is moving at constant speed and turning left, what is the direction of $\vec{F}_{net}$? 7

(x 1pt) If the object is moving at constant speed and turning right, what is the direction of $\vec{F}_{net}$? 3

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 θ 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.

$$\vec{r} = \vec{r}_{planet} - \vec{r}_{star} = \langle 1.41\times10^{10}, -5.71\times10^{10}, 0\rangle m - \langle -5.00\times10^{10}, 0, 0\rangle m = \langle 6.41\times10^{10}, -5.71\times10^{10}, 0\rangle m$$

$$|\vec{r}| = \sqrt{(6.41\times10^{10}m)^2 + (-5.71\times10^{10}m)^2} = 8.58\times10^{10}m$$

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\langle 6.41\times10^{10}, -5.71\times10^{10}, 0\rangle m}{8.58\times10^{10}m} = \langle 0.747, -0.665, 0\rangle$$

$$\vec{F}_{grav} = -G\frac{m_p m_s}{|\vec{r}|^2}\hat{r} = -\left(6.7\times10^{-11}\ N\cdot m^2/kg^2\right)\frac{(6\times10^{24}kg)(2\times10^{30}kg)}{(8.58\times10^{10}m)^2}\langle 0.747, -0.665, 0\rangle$$

$$\Rightarrow \vec{F}_{grav} = \boxed{\langle -8.15\times10^{22}, 7.26\times10^{22}, 0\rangle\ N}$$

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

Since $\hat{v} = \langle 1, 0, 0\rangle$, the parallel direction is $\pm\hat{x}$, so we immediately know that $\left(\frac{d\vec{p}}{dt}\right)_{||} = (\vec{F}_{net})_{||} = \boxed{\langle -8.15\times10^{22}, 0, 0\rangle\ N}$

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

The perpendicular direction is $\pm\hat{y}$, so:

$$\left(\frac{d\vec{p}}{dt}\right)_{\perp} = (\vec{F}_{net})_{\perp} = \boxed{\langle 0, 7.26\times10^{22}, 0\rangle\ N}$$