Phys 172 Exam 1, 2010 fall, Purdue University

What to bring:
1. Your student ID – we will check it!
2. Calculator: any calculator as long as it does not have internet/phone connection
3. Pencils

- Exam will take place in Elliot Hall of Music.
- When entering hall, please take a writing board (available at the entrance).
- Please prepare to be seated in "exam formation" – each other row and each other seat.
- Turn off your phone and keep it in your bag/pocket at all times
- Equation sheet is provided at the end of the exam. You can tear it off and use, you do not have to return it.
- At the end of the exam please turn in your scantron sheet and paper exam to one of the TAs (don't forget to sign your paper exam at the right-top corner).

DO NOT OPEN YOUR EXAM UNTIL TOLD

<u>Practice</u> Exam I, Phys 172, Spring 2010

<u>EXAM # 05</u>

1. Record your two-digit exam version number on ***scantron*** *form in the field "Test/Quiz number". Please do not omit leading zero.*

2. Write your name in the top-right corner here and on the ***scantron*** *form*

3. Record your PUID number in the respective field on your ***scantron*** *form*

Do not use other paper. Write on the back of this test if needed.

The page with major equations is provided with this exam (in the back)

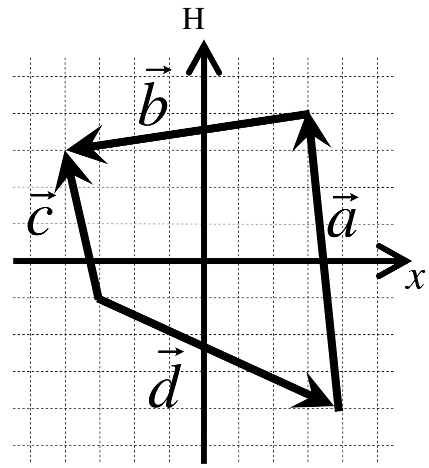
Circle your answers here and on ***scantron*** *form. At the end of the exam, you will return* ***scantron*** *form and this printout with circled answers to your TA.*

Problems 1-3

For the next four problems consider vectors in the diagram shown below, in which each division is equal to 1 m.

Problem 1 (5 pts)

What are the components of the vector $\vec{a}$?



A) <8, -1> m
B) <9, 2> m
C) <-1, 8> m
D) <3, 4> m
E) <4, 3> m

Problem 2 (5 pts)

What is the magnitude of the vector $\vec{a}$?

A) 8.06 m $|\vec{a}| = \sqrt{(-1)^2 + 8^2}$
B) 9 m
C) 8.21 m
D) 8.32 m
E) 5 m

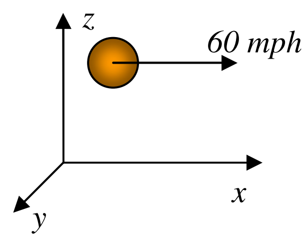
Problem 3 (5 pts)

Which one of the following statements is true about vectors $\vec{a}$, $\vec{b}$, $\vec{c}$ and $\vec{d}$?

A) $\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$
B) $\vec{a} + \vec{b} = \vec{c} - \vec{d}$
C) $\vec{a} + \vec{c} = \vec{b}$
D) $\vec{a} = \vec{c} + \vec{b}$
E) $\vec{a} - \vec{b} = \vec{c}$

Problems 4-5

A tennis ball of mass 57 g is served in horizontal direction along *x*-axis and initially flies at speed 60 mph.



Problem 4 (5 pts)

What is the initial magnitude of its momentum?

A) 3420 kg·m/s

B) 1.5 kg·m/s $\left|\vec{p}\right| \approx mv = 0.057kg \times \dfrac{60\dfrac{miles}{hour} \times 1600\dfrac{meters}{mile}}{3600\dfrac{\sec onds}{hour}}$

C) 1500 kg·m/s

D) 3.42 kg·m/s

E) 22.1 kg·m/s

Problem 5 (5 pts)

What is the magnitude of the *x*-component of this tennis ball after 1 second? (gravitational force on the ball is downwards in -*z* direction)

A) 2.1 kg·m/s

B) 3420 kg·m/s

C) 1.5 kg·m/s, since there is no force component in horizontal direction momentum component in this direction cannot changing (momentum principle)

D) 3900 kg·m/s

E) 22.1

Problem 6 **(5 pts)**
An electron was accelerated to from a speed 0.9999c, to 0.99999c in 1 second (c=3×10^8 m/s is the speed of light). What was the average force applied to an electron during that second? Assume unidirectional motion. Mass of an electron is 9×10^{-31} kg.

A) 4.1×10^{-20} N
B) 2.4×10^{-26} N
C) 3.8×10^{-24} N
D) 3.8×10^{-20} N
E) 1.6×10^{-21} N

$$\left|\vec{p}_i\right| = \gamma mv = \frac{9\times10^{-31}\,kg\cdot 0.9999\cdot 3\times10^{8}}{\sqrt{1-\left(\frac{0.9999c}{c}\right)^2}} = 1.91\times10^{-20}\,kg\cdot m/s \qquad \left|\vec{p}_f\right| \approx 6.04\times10^{-20}\,kg\cdot m/s$$

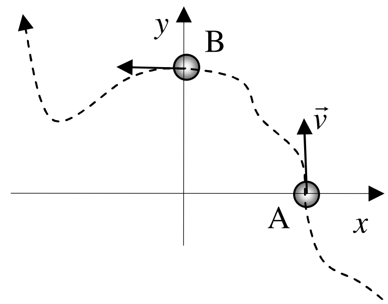
$$\vec{F} = \Delta\vec{p}/\Delta t \qquad \left|\vec{F}\right| = \left(6.04\times10^{-20}\,kg\cdot m/s - 1.91\times10^{-20}\,kg\cdot m/s\right)/1s = 4.13\times10^{-20}\,N$$

Problem 7 **(5 pts)**
If an object moves at constant speed, you can irrefutably conclude that:

A) The object may be interacting with other objects in the universe, but the net interaction is zero
B) The object does not interact with anything in the universe
C) The net interaction with other objects in universe may be not zero, but it is constant in time
D) The object does not obey laws of physics
E) There is no gravity acting on that object

Problems 8-10

An object of mass 2 kg moves at a constant speed 0.5 m/s along a path as shown.



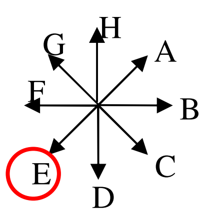
Problem 8 (5 pts)

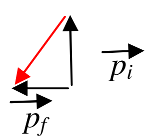
What is the magnitude of the momentum change $|\Delta\vec{p}|$ when the object travels from point A to point B?

A) 0 kg·m/s
B) 1 kg·m/s
C) 0.5 kg·m/s
D) 2 kg·m/s
E) 1.41 kg·m/s

Problem 9 (5 pts)

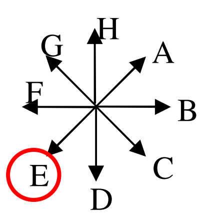
Which vector best represents the direction of $\Delta\vec{p}$ as the object travels from point A to B?





Problem 10 (5 pts)

What is the vector representing the direction of the average net force applied to the object while it traveled from A to B?



- momentum principle - the force is in the same direction as the change in momentum

Problems 11-14

A 70 kg hockey layer sliding freely on his knees (no friction) on horizontal icy surface with velocity <-10,0,0> m/s. He then catches a 160g puck flying at speed <40,20,2> m/s (*z*-axis is vertical)

Problem 11 (5 pts)

What is the momentum of the player before he catches the puck?

A) <-700,0,0> kg·m/s $\vec{p} \approx m\vec{v} = 70kg \times \langle -10,0,0 \rangle m/s$

B) <210,1400,140> kg·m/s

C) <922,3211,0> kg·m/s

D) <432,4,0> kg·m/s

E) <4.32,0.04,0> kg·m/s

Problem 12 (5 pts)

What is the velocity of the player after he catches the puck? Note that the guy still slides along horizontal surface of the ice.

A) <9.9, 0.046, 0.0046> m/s

B) <-9.9, 0.046, 0> m/s

C) <-640, 3.2, 0.32> m/s

D) <-9.58, 0.003, 0.001> m/s

E) <-9.58, 0.003, 0> m/s

$$\vec{p}_{player} + \vec{p}_{puck} = \vec{p}_{total} = const$$

$$\vec{p}_{total,i} = 70kg\langle -10,0,0 \rangle m/s + 0.16kg\langle 40,20,2 \rangle m/s = \langle -693.6,3.2,0.32 \rangle kg \cdot m/s$$

$$\vec{p}_{total,f} = (70kg + 0.16kg)\langle v_x, v_y, v_z \rangle = \vec{p}_{total,i} = \langle -693.6,3.2,0.32 \rangle kg \cdot m/s$$

$$v_x = p_{total,x} / m_{total} = (-693.6kg \cdot m/s)/(70kg + 0.16kg) = -9.89 m/s$$

$$v_y = p_{total,y} / m_{total} = (3.2kg \cdot m/s)/(70kg + 0.16kg) = 0.046 m/s$$

$$v_x = (-700)$$

$$70kg\langle -10,0,0 \rangle m/s + 0.16kg\langle 40,20,2 \rangle m/s = (70kg + 0.16kg)\langle v_x, v_y, v_z \rangle)$$

(*z*-component must be still zero since the player cannot leave ice – this component is not conserved in the system player-puck due to interaction with the Earth)

Problem 13 (5 pts)

What is the change in the momentum of the guy?

A) <60, 5, 1> kg·m/s

B) <600, 0, 0> kg·m/s

C) <0.06, 1, 0> kg·m/s

D) <7.7, 3.2,0> kg·m/s

E) <-50, 0, 0> kg·m/s

Problem 14 (5 pts)

What is the change in the momentum of the puck?

A) <60, 5, 1> kg·m/s

B) <600, 0, 0> kg·m/s

C) <0.06, 1, 0> kg·m/s

D) <-7.7, -3.2, -0.32> kg·m/s

E) <-50, 0, 0> kg·m/s

Mark your recitation time with an X

PHYS 172 - Spring 2010
Hand-Graded part of *Practice* Exam 1:

Name (Print):________________________________

Signature:__________________________________

PUID:_____________________________________

	Tu	W	Th	F
8.30				
9:30				
10:30				
11:30				
12:30				
1:30				
2:30				
3:30				
4:30				

When you use a fundamental principle you must explain clearly what physical system you are applying it to and which objects in the system's surroundings are interacting significantly with it.

Problem 1 (20 points)

You see your 10 kg bag sitting at rest on the floor at the airport baggage claim, and you rush over to grab it. You jerk the bag off the ground by pulling on it with a constant force of 130 N, at an angle of 70° above horizontal, for 0.1 seconds. The force of your pull is in the x-y plane (where the x-axis is parallel with the ground, and the y-axis points straight up in the air).

We want to know the velocity of the bag at the end of this 0.1 second period of tugging, and also the total distance through which the bag moved.

1.1. Define the system you're using in this problem.

System = bag.
You can chose a different system – but you will have to stick to that system in the following questions.

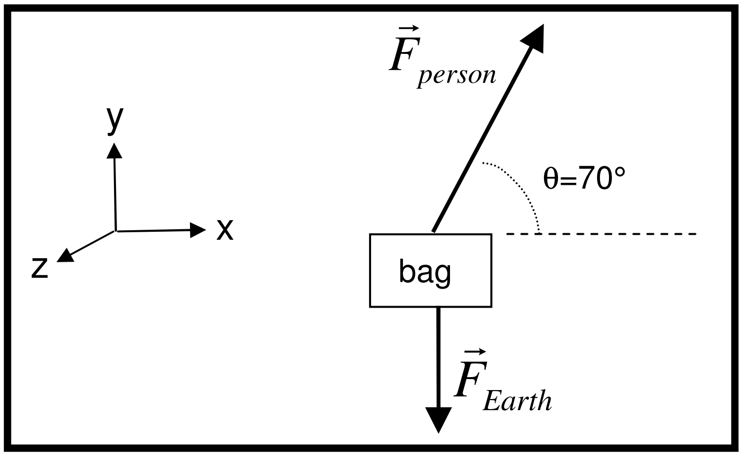
1.2. List the external objects that interact significantly with the system. Make a carefully labeled diagram showing their interaction with the system. List an object that doesn't interact significantly with the system.

Significant interaction: Earth, person

Insignificant:
Sun, Jupiter etc.

See diagram on the next page.

Note: the diagram depends on the choice of the system.
If you chose different system you should stick to it and use it in the diagram



1.3. Use the momentum principle to find the velocity of the bag at the end of the 0.1 second period of time. Show all steps, include units, and circle the final answer. (*Note: You're not being asked for the speed of the box.)*

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

Force:

$$\vec{F}_{net} = \vec{F}_{person} + \vec{F}_{Earth}$$

$$\vec{F}_{Earth} = \langle 0, -mg, 0\rangle = \langle 0, -98, 0\rangle N$$

$$\vec{F}_{person} = \langle F_{person}\cos\theta, F_{person}\sin\theta, 0\rangle = \langle 44.5, 122, 0\rangle N$$

$$\vec{F}_{net} = \vec{F}_{person} + \vec{F}_{Earth} = \langle F_{person}\cos\theta, F_{person}\sin\theta - mg, 0\rangle N$$

From the momentum principle find the momentum after 0.1s:

$$\vec{p}_f - \vec{p}_i = \vec{F}_{net}\Delta t$$

$$\vec{p}_f - 0 = \langle F_{person}\cos\theta, F_{person}\sin\theta - mg, 0\rangle \Delta t$$

$$\vec{p}_f = \langle 4.45, 2.42, 0\rangle kg\frac{m}{s}$$

Knowing momentum we can find the velocity:

$\vec{p} = \gamma m\vec{v} \approx m\vec{v}$ (use nonrelativistic approximation, $v << c$)

And the answer is:

$$\boxed{\vec{v}_f \approx \vec{p}_f / m = \langle 0.45, 0.24, 0\rangle m/s}$$

1.4. Through what total distance did the bag move during the 0.1 second period of time? Show all steps, include units, and circle the final answer.

Start from the position update (which is another form of definition of average velocity):

$$\Delta\vec{r} = \vec{v}_{ave}\Delta t$$

Under constant force, the average velocity is:

$$\vec{v}_{ave} = \tfrac{1}{2}\left(\vec{v}_f + \vec{v}_i\right) = \langle 0.22, 0.12, 0\rangle\, m/s$$

Where initial velocity was 0. Therefore:

$$\Delta\vec{r} = \vec{v}_{ave}\Delta t = \langle 0.022, 0.012, 0\rangle\, m$$

And the distance is:

$$\boxed{d = \sqrt{\left(\Delta\vec{r}\right)_x^2 + \left(\Delta\vec{r}\right)_y^2} = 0.025\, m}$$

Problem 2 (10 points)

As you are walking down a hallway in the Physics building you overhear two students discussing a Phys 172 problem in which two boxes are being moved across a loading dock. The smaller of the two boxes is on top of the larger one. As a worker pushes on the larger box, both boxes move together with increasing speed across the level, polished concrete floor.

One student says "The worker must be exerting a force on the top box, otherwise its motion would not be changing and it would be left behind as the bottom box moves." The other student responds "No, the worker isn't exerting any significant force on the top box because he isn't in contact with it. The motion of the top box does change though, so, it must be interacting significantly with some other object in its surroundings."

Starting from fundamental principles, how do you explain the changing motion of the top box in this situation? What objects in its surroundings is the top box interacting significantly with?

The second student is correct. The worker is not interacting significantly with the top box because he is not in contact with it.

The top box is interacting significantly with the Earth and with the bottom box*. It is interacting gravitationally with the Earth and it is interacting with the bottom box by contact.

The vertical components of the forces exerted on the top box by the Earth and by the bottom box are equal in magnitude but opposite in sign so they cancel. Applying the momentum principle to the system consisting of the top box alone, we see that this explains why the vertical component of the momentum of the top box remains zero.

There is a horizontal component of static-friction force exerted on the top box by the bottom one. This is the net force on the system consisting of the top box alone and, so, applying the momentum principle to that system explains why the horizontal component of the momentum of the top box increases.

* Note: The top box is also in contact with the air (atmosphere). Because the net (buoyant) force exerted on the box by the air in negligible in this case, we did not mention it.

Equation list for exam I, PHYS 172, spring 2010

$$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t} \equiv \frac{\vec{r}_f - \vec{r}_i}{t_f - t_i} \qquad \vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} \equiv \frac{d\vec{r}}{dt} \qquad \vec{r}_f = \vec{r}_i + \vec{v}_{avg}\left(t_f - t_i\right)$$

$$r_f = r_i + \frac{v_i + v_f}{2}\left(t_f - t_i\right)$$

$$\vec{p} = \gamma m \vec{v} \qquad \gamma = \frac{1}{\sqrt{1 - \left(\frac{|\vec{v}|}{c}\right)^2}} \qquad \vec{v} = \frac{\vec{p}/m}{\sqrt{1 + \left(\frac{|\vec{p}|}{mc}\right)^2}}$$

$$\Delta \vec{p} = \vec{F}_{net}\Delta t \qquad \vec{p}_f = \vec{p}_i + \vec{F}_{net}\Delta t \qquad \frac{d\vec{p}}{dt} = \vec{F}_{net} \qquad \Delta \vec{p}_{system} + \Delta \vec{p}_{surrounding} = \vec{0}$$

$$\frac{d\vec{p}}{dt} = \frac{d|\vec{p}|}{dt}\hat{p} + |\vec{p}|\frac{d\hat{p}}{dt} \qquad \left(\frac{d\vec{p}}{dt}\right)_{\perp} = p\frac{v}{R} = F_{\perp} \qquad \left(\frac{d\vec{p}}{dt}\right)_{\parallel} = \frac{dp}{dt} = F_{\parallel}$$

$$\left|\vec{F}_{spring}\right| = k_S|s| \qquad \frac{F_T}{A} = Y\frac{\Delta L}{L} \qquad k_s = \frac{A}{L}Y \qquad k_{\text{interatomic}} = Yd$$

$$\vec{F}_{grav\ \text{on 2 by 1}} = -G\frac{m_2 m_1}{|\vec{r}_{2-1}|^2}\hat{r}_{2-1} \qquad \vec{F}_{\text{elec on 2 by 1}} = \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_1}{|\vec{r}_{2-1}|^2}\hat{r}_{2-1}$$

$$\Delta x \Delta p_x \geq h$$

$$\ddot{x}(t) = -\frac{k}{m}x(t) \qquad x = A\cos(\omega t) \qquad \omega = \sqrt{\frac{k_s}{m}} \qquad T = \frac{2\pi}{\omega} \qquad f = \frac{1}{T}$$

Constants:

$G = 6.7\times10^{-11}\ \frac{\text{N}\times\text{m}^2}{\text{kg}^2}$ $\qquad \frac{1}{4\pi\varepsilon_0} = 9\times10^9\ \frac{\text{N}\times\text{m}^2}{\text{C}^2}$ $\qquad h = 6.6\times10^{-34}\ \text{kg}\cdot\text{m}^2/\text{s}$

$c = 3\times10^8$ m/s $\qquad g = 9.8$ N/kg $\qquad N_A = 6\times10^{23}\ \text{mol}^{-1}$

Geometry:

$\pi = 3.14$

Circle: $circumference = 2\pi r$, $area = \pi r^2$

Sphere: $area = 4\pi r^2$, $volume = (4/3)\pi r^3$