Physics 2211: *Matter and Interactions*

Class III (interactions and momentum)

Todays objective:

Momentum principle and iterations

$$\frac{d\vec{p}}{dt} = \vec{F}_{net}$$

$$d\vec{p} = \vec{F}_{net}\,dt$$

E-mail: Flavio.Fenton@physics.gatech.edu

Howey Room C203

Office Hours: Weds 7-9 am

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E-mail: Flavio.Fenton@physics.gatech.edu

PLUS Sessions: Bagas Widianto

Tuesdays and Thursdays from

7:00-8:00 PM in CULC 123.

Physics 2211: *Matter and Interactions*

- **The Momentum Principle:** *The change in momentum of a system is equal to the net interaction (force) acting on the system by the surroundings multiplied by the duration of the interaction*
  - System: *One or more objects of interest*
  - Surroundings: *Everything else in the Universe*
  - Net Force: *The sum of all the interaction (forces)*
- **Newton's Second Law**
  - True for all forces
  - Allows us to quantify the interactions of a system and its surroundings.

$$\frac{d\vec{p}}{dt} = \vec{F}_{net}$$

$$\boxed{\Delta\vec{p} = \vec{F}_{net}\Delta t}$$

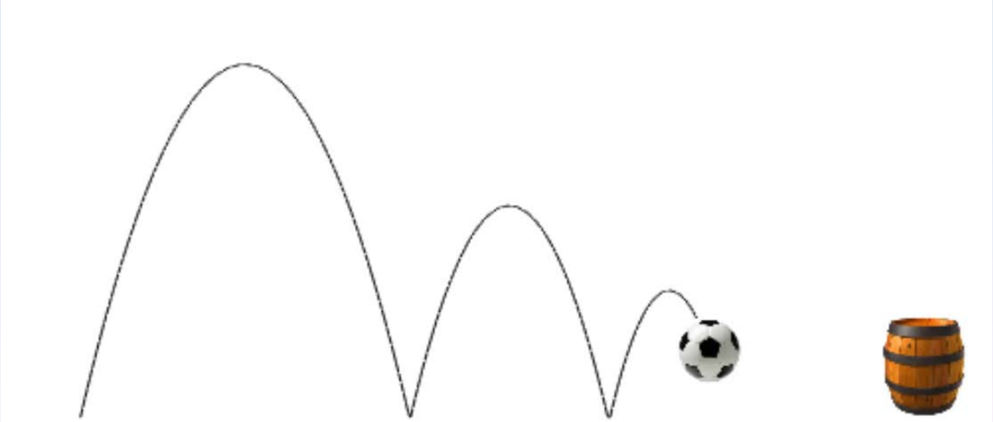
- **Applying the momentum principle**
  1. Chose your system, everything else belongs in the surroundings.
  2. Draw a force diagram
     - All forces must be due to interactions with surroundings
  3. Chose your time interval
     - Given or estimated
  4. Substitute known values into the equation and solve for the unknowns
  5. Check units and reasonableness of answer

- **The momentum principle**

$$\boxed{\Delta \vec{p} = \vec{F}_{net} \Delta t}$$

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

Physics of kicking a ball:



What is the system?
What are the surroundings?
What forces are acting on the system?
Important!!: And <u>when?</u>

Yes: F_gravitation is all the time
No: F_Kicking is NOT all the time!
What if we consider air friction?

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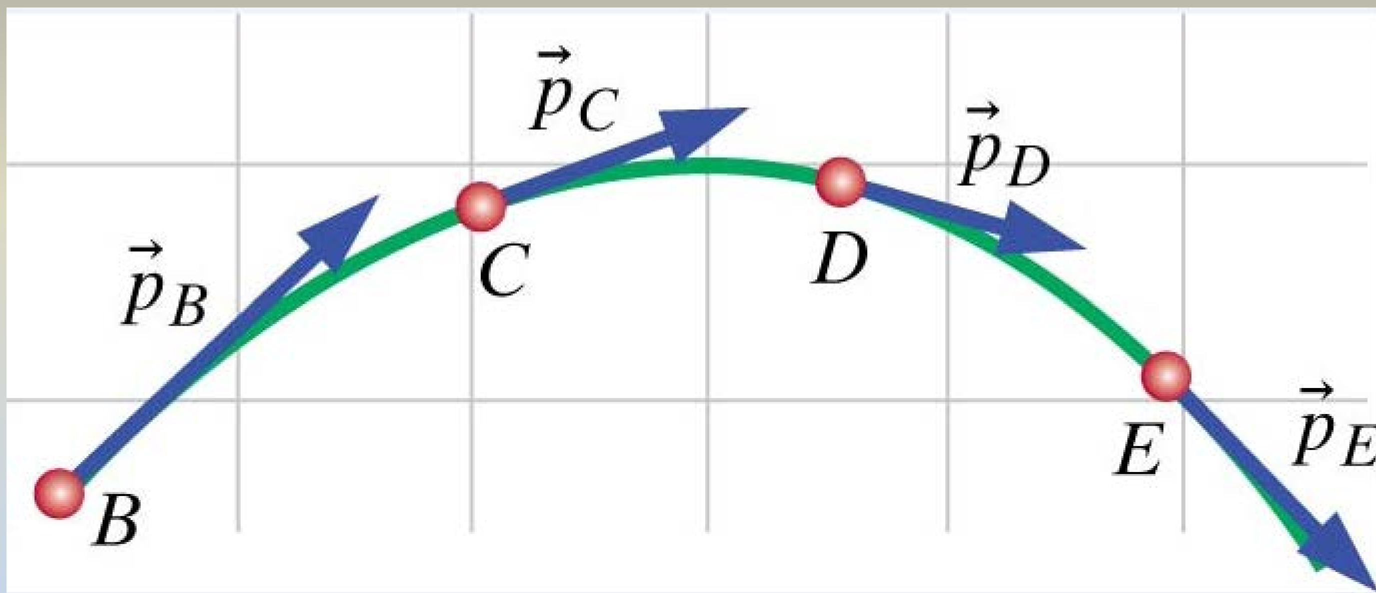
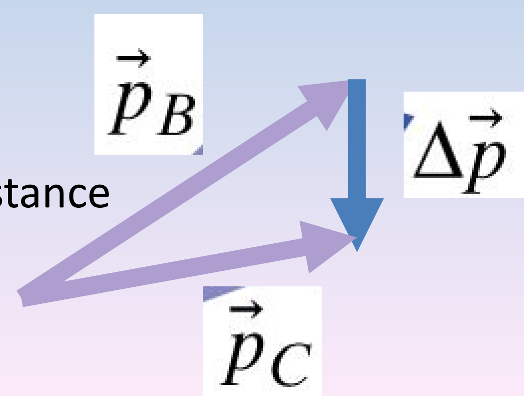
$$\Delta \vec{p} = \vec{F}_{net} \Delta t$$

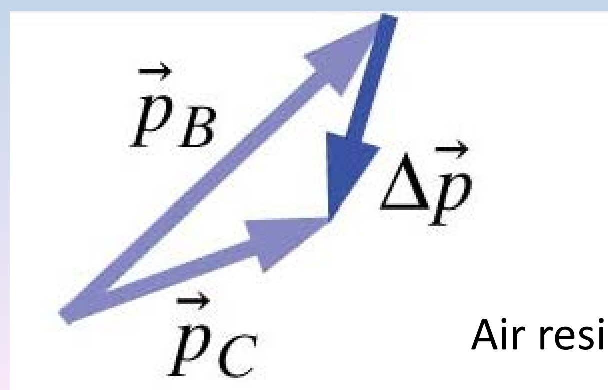
Note: This equation tell us that:
The direction of change in Momentum, has to be equal to the Net Force



No-Air resistance



VS



Air resistance

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Note: This equation tell us that:
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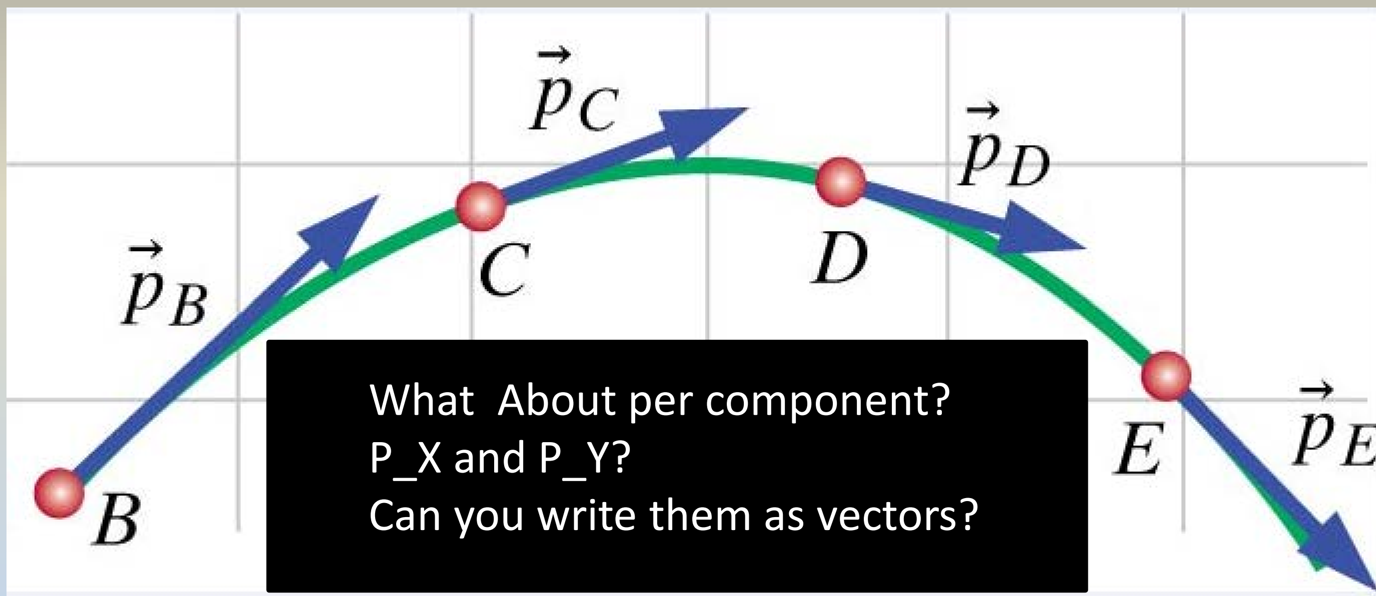
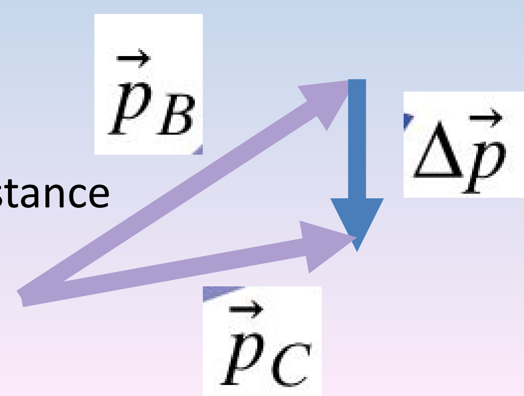
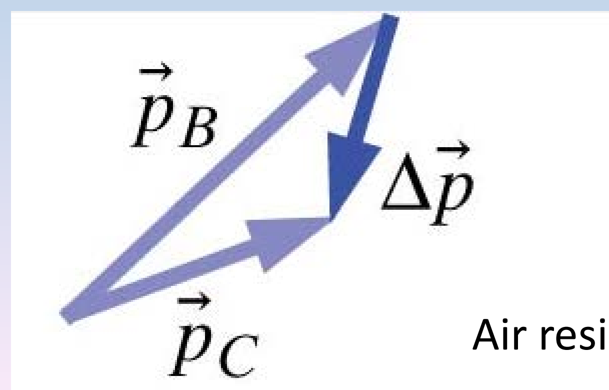


No-Air resistance

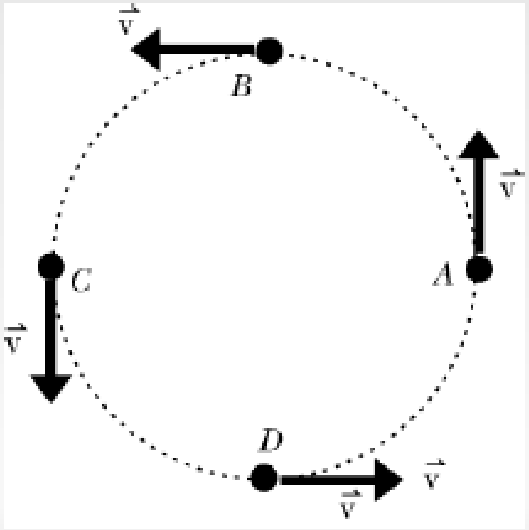


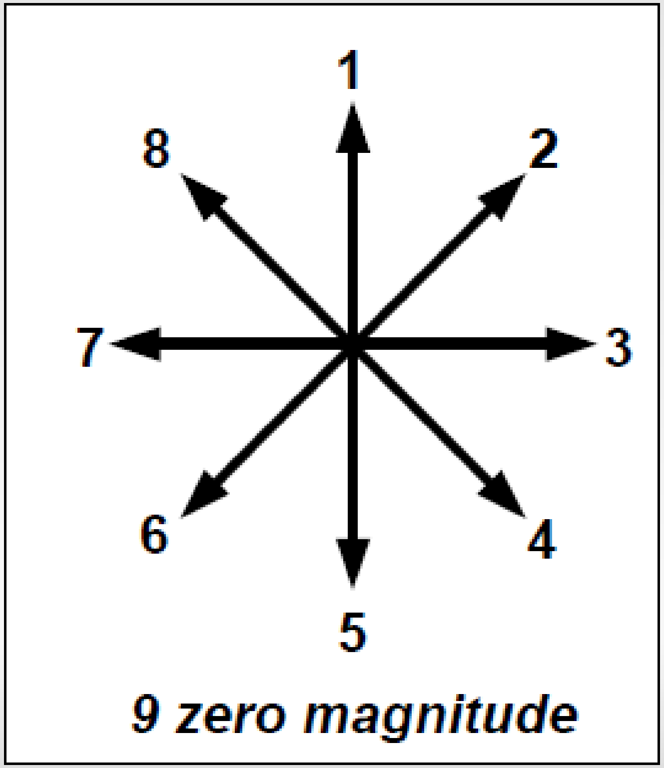
VS



Air resistance

- **Changes in momentum indicate an interaction**
  - **Clicker:** *A child rides on a merry-go-round, traveling from location A to location C at a constant speed. What is the direction of the child's change in momentum, between A and C?*





Physics 2211: *Matter and Interactions*

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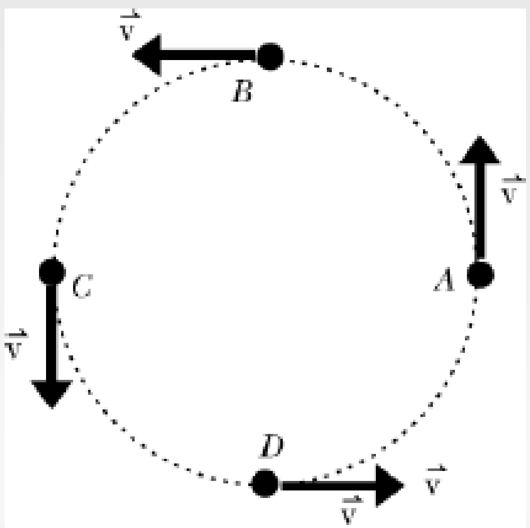
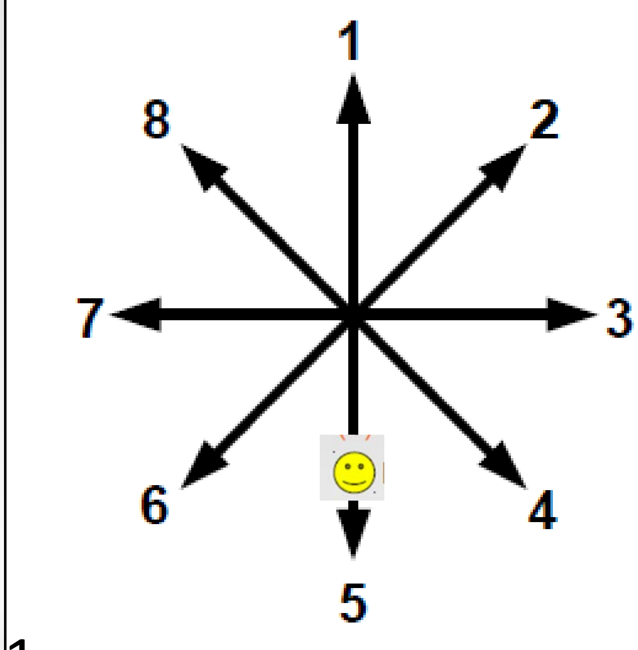




Assume $V_A = \langle 0,5,0 \rangle$ and $V_C = \langle 0,-5,0 \rangle$, m=1

What is $|\Delta \vec{P}|$ and $\Delta|\vec{P}|$?

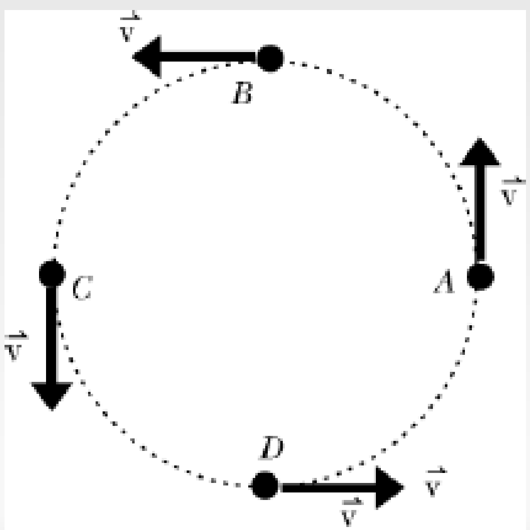
$|\langle 0 , -10, 0 \rangle| = 10$ and 0 (so not the same!)

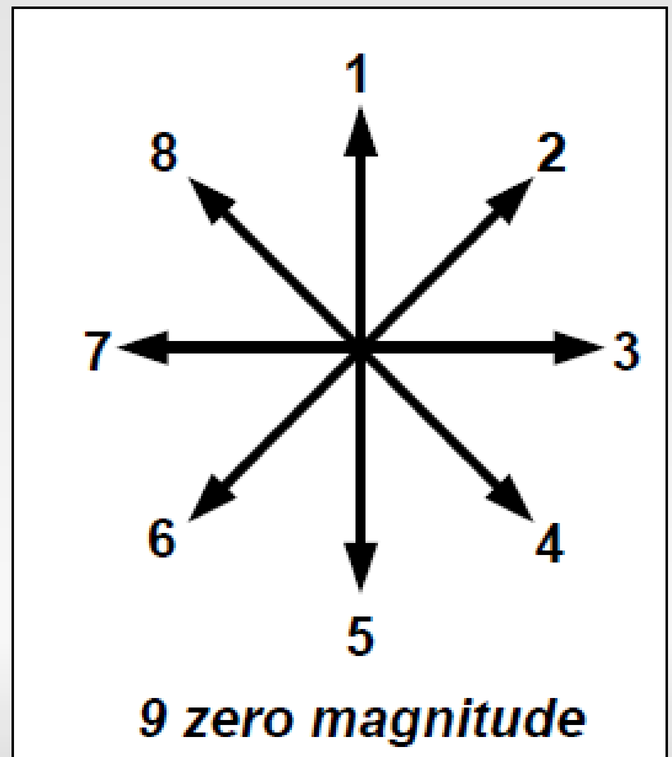
$$|\Delta \vec{p}| \neq \Delta |\vec{p}|$$

Physics 2211: *Matter and Interactions*

- **Changes in momentum indicate an interaction**
  - **<u>Clicker:</u>** *A child rides on a merry-go-round, traveling from location A to location C at a constant speed. What is the direction of the child's change in momentum, between A and C?*

B





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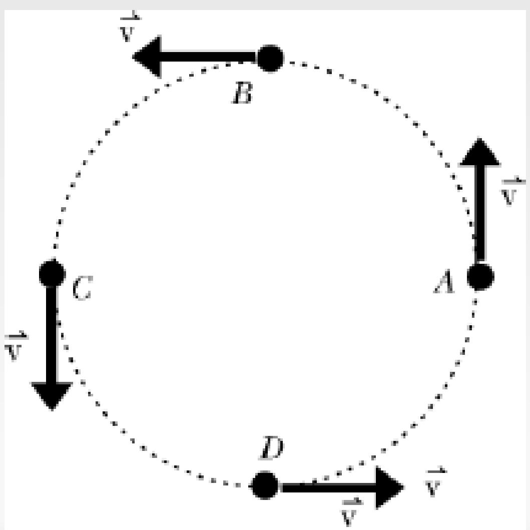
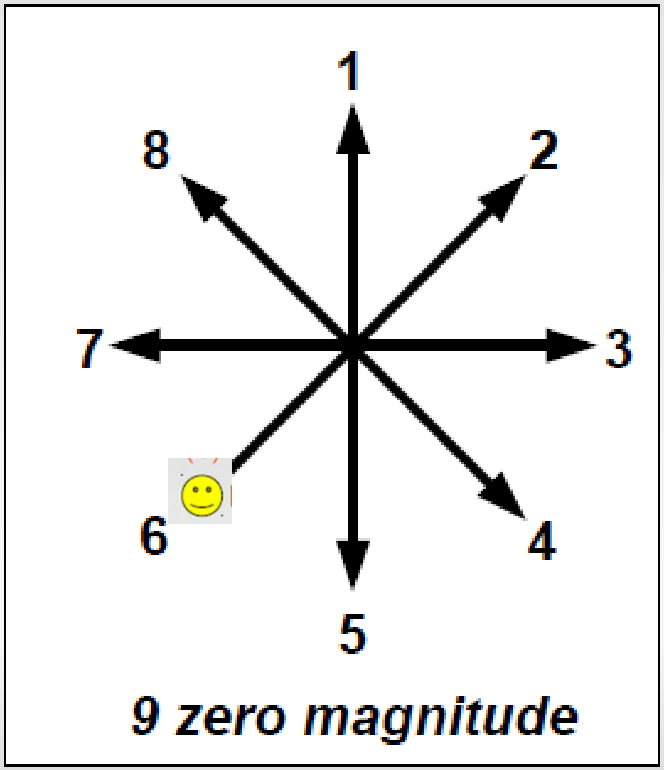




Another Example, so let's remember:

- **Applying the momentum principle**
  1. Chose your system, everything else belongs in the surroundings.
  2. Draw a force diagram
     - All forces must be due to interactions with surroundings
  3. Chose your time interval
     - Given or estimated
  4. Substitute known values into the equation and solve for the unknowns
  5. Check units and reasonableness of answer

Physics 2211: *Matter and Interactions*

On the bucket

- **SRS:** *A bucket of chicken is being lifted up a well at a constant speed by a rope. All frictional effects are negligible. In this situation, forces on the bucket of chicken are such that:*

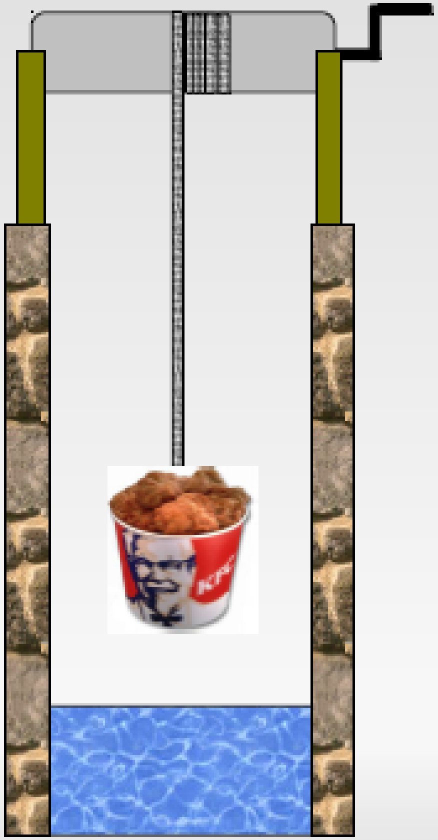
  (1) The upward force by the rope is greater than the downward force of gravity

  (2) The upward force by the rope is equal to the downward force of gravity.

  (3) The upward force by the rope is smaller than the downward force of gravity.

  (4) The upward force by the rope is greater than the sum of the downward force of gravity and a downward force due to the air.

  (5) None of the above. (The bucket goes up because the rope is being shortened, not because an upward force is exerted on the bucket by the rope).



Physics 2211: *Matter and Interactions*

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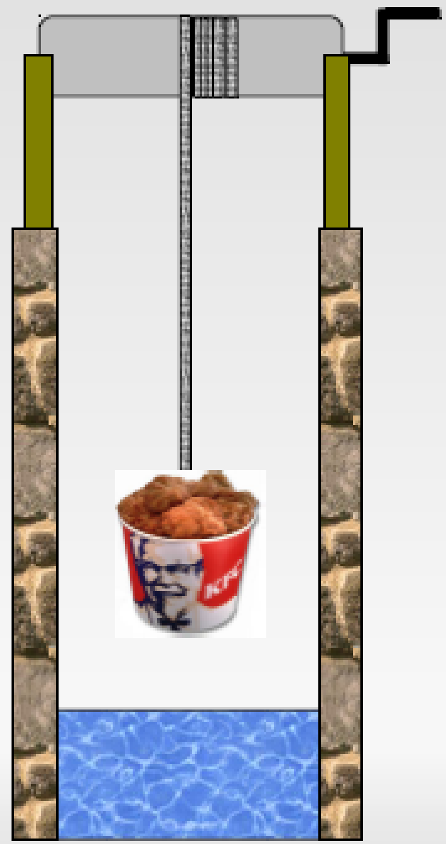
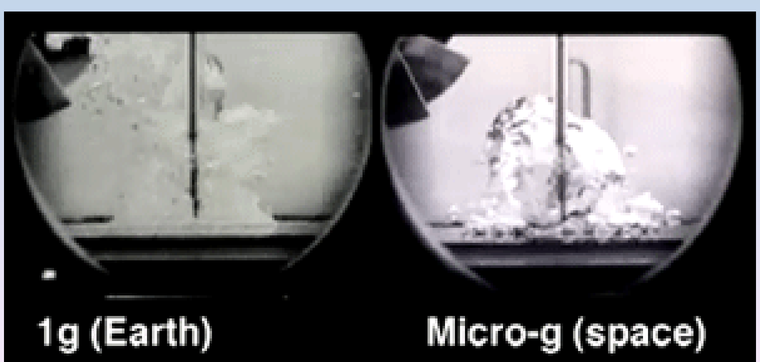
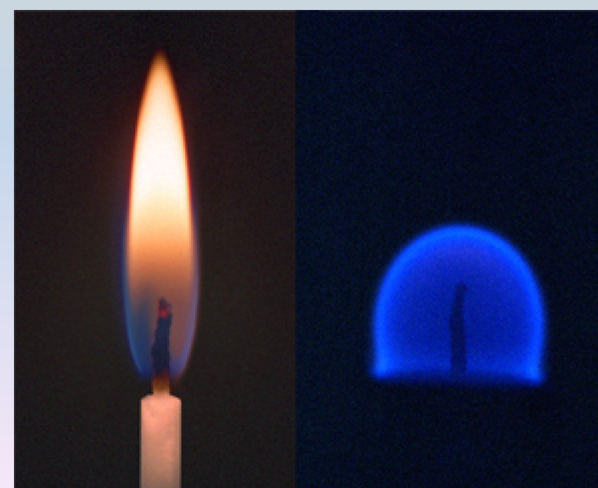


If the velocity is increasing, what would be the answer?

Having fun with $\frac{d\vec{p}}{dt} = 0$

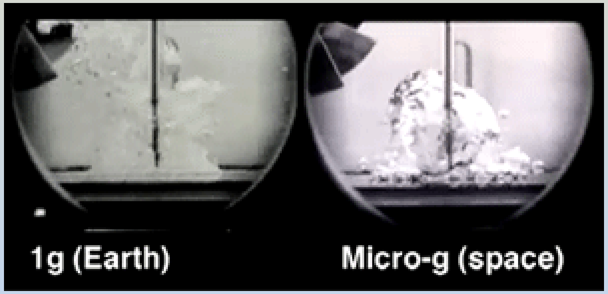
- Explosions?
- Fire?
- Boiling water?





Having fun with $\frac{d\vec{p}}{dt} = 0$

- Fire and Explosions?
- Liquids?
- Motion?



- **SRS: Which cart(s) experience a net force to the left?**
  Cart A moves to the left at a constant speed.
  Cart B moves to the left, gradually speeding up.
  Cart C moves to the left, gradually slowing down.

  (1) A only
  (2) B only
  (3) C only
  (4) A and B
  (5) B and C
  (6) A and C
  (7) A, B, and C

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Q2.2.a

An object is moving in the +x direction. Which of the following statements about the net force acting on the object could be true? A. The net force is in the +x direction B. The net force is in the –x direction C. The net force is zero	1) A only 2) B only 3) C only 4) A and B 5) B and C 6) A and C 7) A, B, and C

Q2.2.a

An object is moving in the +x direction. **Which of the following statements about the net force acting on the object could be true?** **A. The net force is in the +x direction** **B. The net force is in the –x direction** **C. The net force is zero**	**1) A only** **2) B only** **3) C only** **4) A and B** **5) B and C** **6) A and C** **7) A, B, and C** 

Q2.3.b

A hockey puck is sliding along the ice with nearly constant momentum < 10, 0, 5 > kg m/s when it is suddenly struck by a hockey stick with a force < 0, 0, 2000 > N that lasts for only 3 milliseconds (3e-3 s). What is the new (vector) momentum of the puck?	1) < 10, 0, 11 > kg·m/s 2) < 0, 0, 6 > kg·m/s 3) 14.86 kg·m/s 4) < 16, 0, 11 > kg·m/s 5) < 0, 0, 30 > kg·m/s

Q2.3.b

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What if I ask you next, what would be the momentum 1 second later?
(assume no friction bye the ice)

Important implications of the Momentum Principle

- If the net force is zero, there is no change in momentum

- Force in one coordinate can not affect the momentum in a different coordinate.

Example: F_x only affects P_x can not affect P_y or P_z

Example2: Object with Px and force Fy what happens to Px?

Nothing

$$p_{fx} = p_{ix} + F_{\text{net},x}\,\Delta t$$

$$p_{fy} = p_{iy} + F_{\text{net},y}\,\Delta t$$

$$p_{fz} = p_{iz} + F_{\text{net},z}\,\Delta t$$

Duck example

Some problems with the HW

- Check for units and make sure they are correct!
- Check for directions (Direction of vectors,
  magnitudes Vs vectors,
  which Vavg to use , etc…)
- Iterative cases.

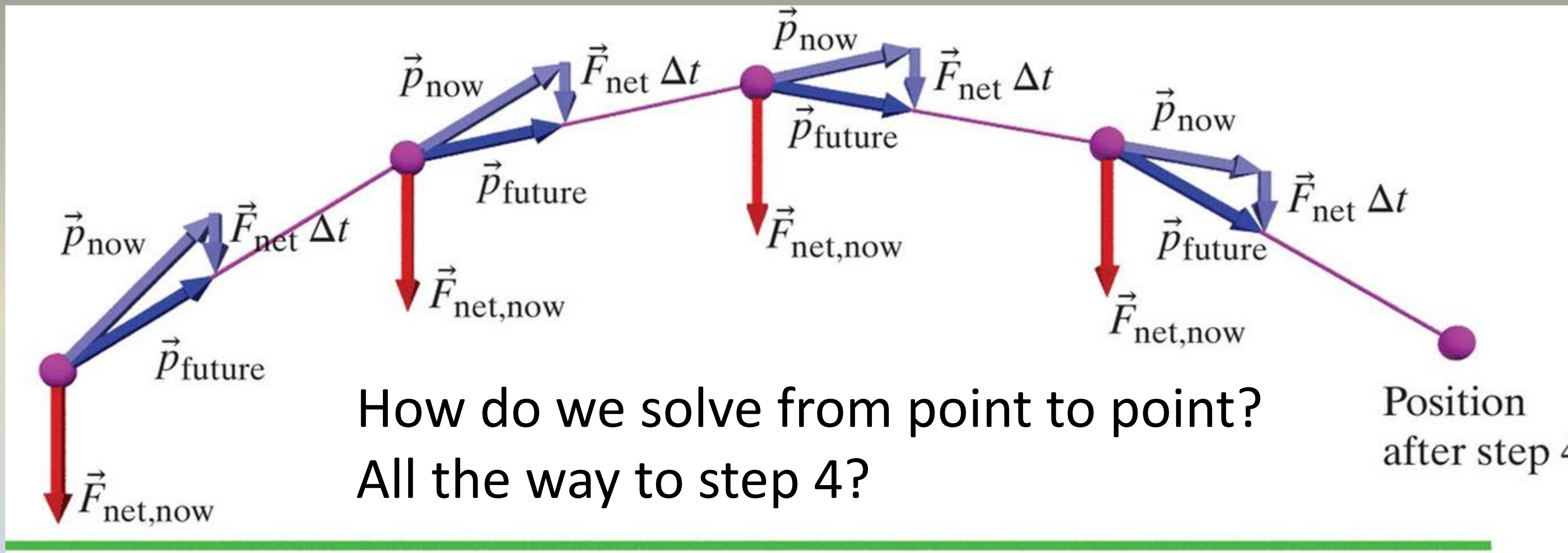
Iterative solution

- Calculate the net force $\vec{F}_{\mathrm{net,now}}$ acting on the system
- Update momentum: $\vec{p}_{\mathrm{future}} = \vec{p}_{\mathrm{now}} + \vec{F}_{\mathrm{net,now}}\Delta t$
- Update position: $\vec{r}_{\mathrm{future}} = \vec{r}_{\mathrm{now}} + \vec{v}_{\mathrm{avg}}\Delta t$

repeat!

Physics 2211: *Matter and Interactions*

How to solve the projectile motion in a computer?



How do we solve from point to point?
All the way to step 4?

Iterative solution

- Calculate the net force $\vec{F}_{\text{net,now}}$ acting on the system
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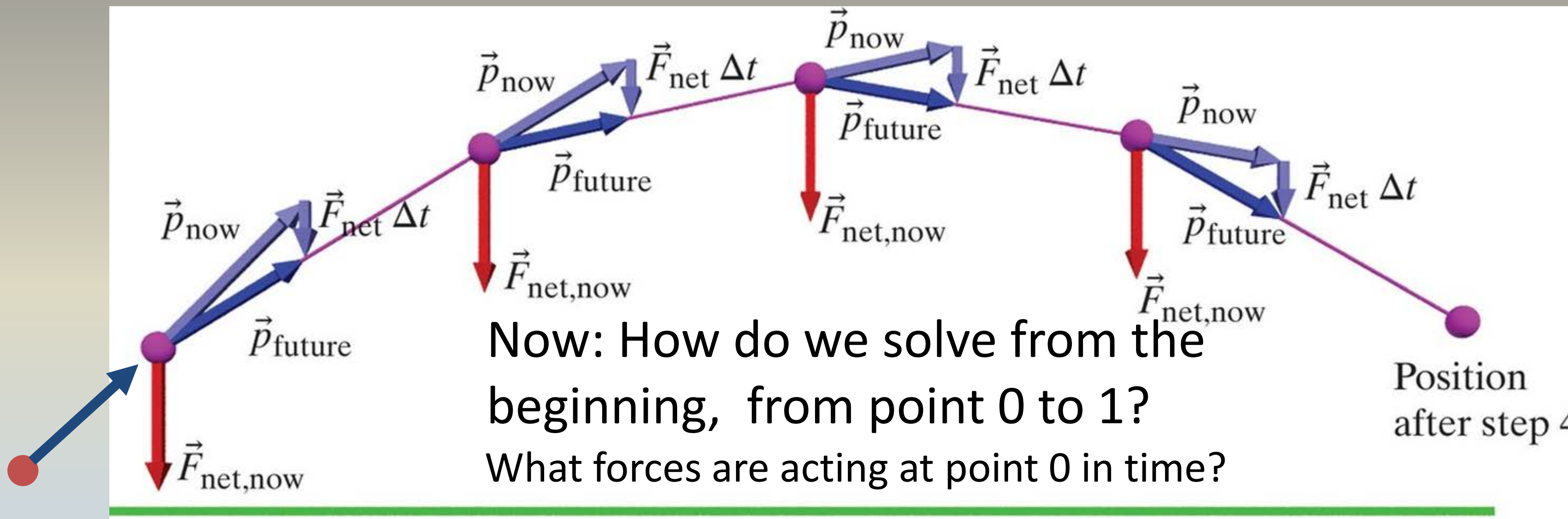
repeat!

Use:
$V_{avg} = P_f/m$

How to solve the projectile motion in a computer?



Now: How do we solve from the beginning, from point 0 to 1?

What forces are acting at point 0 in time?

Iterative solution

- Calculate the net force $\vec{F}_{net,now}$ acting on the system
- Update momentum: $\vec{p}_{future} = \vec{p}_{now} + \vec{F}_{net,now}\Delta t$
- Update position: $\vec{r}_{future} = \vec{r}_{now} + \vec{v}_{avg}\Delta t$

repeat!

Use:

$V_{avg} = P_f/m$

- **SRS:** *The x-component of momentum of an object is found to increase with time:*

$t = 0$ s $p_x = 30$ kg m/s
$t = 1$ s $p_x = 40$ kg m/s
$t = 2$ s $p_x = 50$ kg m/s
$t = 3$ s $p_x = 60$ kg m/s

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

(1) $F_{net,x} = 0$

(2) $F_{net,x}$ is constant

(3) $F_{net,x}$ is increasing with time

(4) Not enough information

- **SRS:** *The x-component of momentum of an object is found to increase with time:*

t = 0 s p_x = 30 kg m/s
t = 1 s p_x = 40 kg m/s
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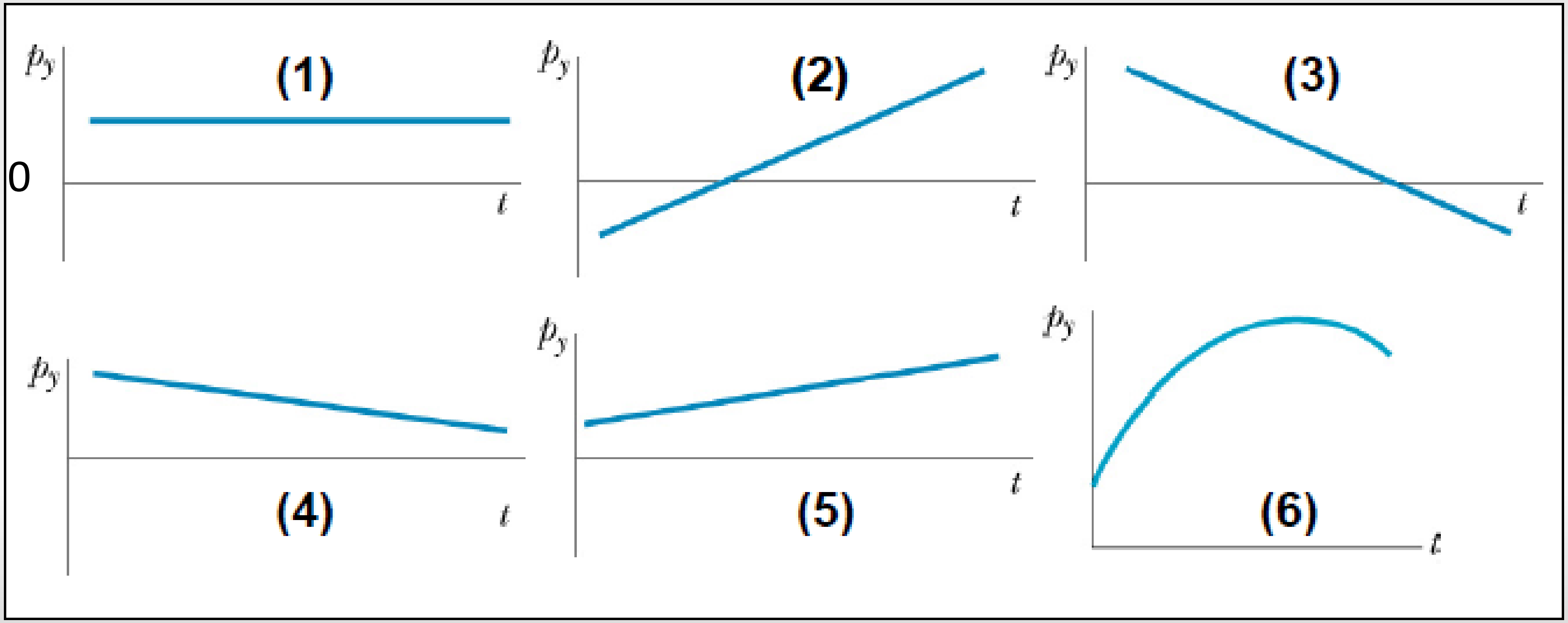
Physics 2211: *Matter and Interactions*

- **SRS:** *The initial momentum of the kicked ball was < 1.5, 3.5, 0 > kg m/s. The final momentum of the ball was < 1.5, 1.05, 0 > kg m/s. Which graph correctly shows P_y for the ball during this 0.5 s?*



Physics 2211: *Matter and Interactions*

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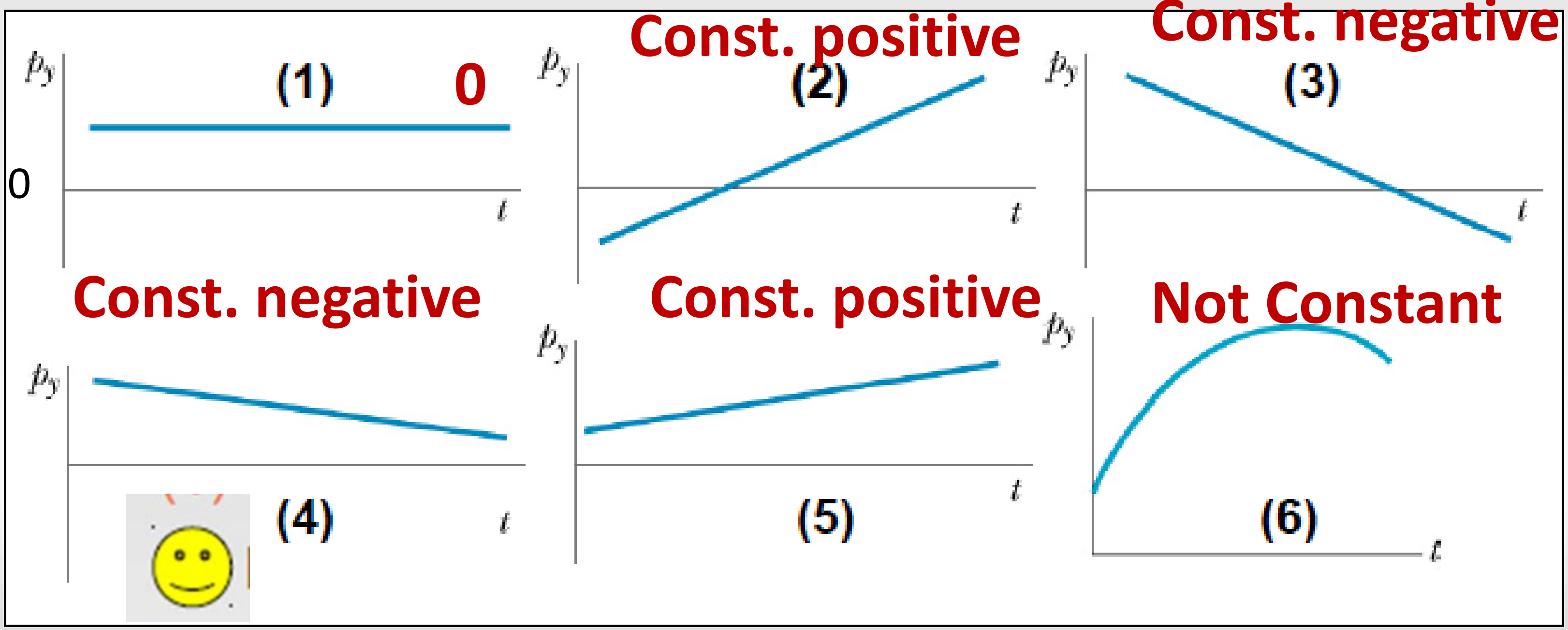

What can we say about the force for each case?

The Kinematic Equations

$$v = v_0 + at$$

$$\Delta x = v_0 t + \tfrac{1}{2} a t^2$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$\Delta x = \bar{v} t = \tfrac{1}{2}(v + v_0)t$$

$$\Delta x = vt - \tfrac{1}{2} a t^2$$

You all know these equations, but where did they came from?

Yes! From $\dfrac{d\vec{p}}{dt} = \vec{F}_{net}$ when $\vec{F}_{Net}$ = Constant

How to solve the projectile motion in a computer?

8. **0/3 points** MI4 2.1.013. [3220153]

A Ping-Pong ball is acted upon by the Earth, air resistance, and a strong wind. Here are the positions of the ball at several times.

Early time interval:

At $t = 13.40$ s, the position was $\langle 4.65, 3.06, -8.45 \rangle$ m.
At $t = 13.46$ s, the position was $\langle 4.72, 2.87, -9.35 \rangle$ m.

Late time interval:

At $t = 16.40$ s, the position was $\langle 10.77, 11.14, -54.35 \rangle$ m.
At $t = 16.46$ s, the position was $\langle 10.95, 11.65, -55.25 \rangle$ m.

(a) In the early time interval, from $t = 13.40$ s to $t = 13.46$ s, what was the average momentum of the ball? The mass of the Ping-Pong ball is 2.7 grams $(2.7 \times 10^{-3}$ kg). Express your result as a vector.

$\vec{p} =$ ____ kg · m/s

(b) In the late time interval, from $t = 16.40$ s to $t = 16.46$ s, what was the average momentum of the ball? Express your result as a vector.

$\vec{p} =$ ____ kg · m/s

(c) In the time interval from $t = 13.40$ s (the start of the early time interval) to $t = 16.40$ s (the start of the late time interval), what was the average net force acting on the ball? Express your result as a vector.

$\vec{F}_{net} =$ ____ N

How to solve the projectile motion in a computer?

8. 0/3 points

A Ping-Pong ball is acted upon by the Earth, air resistance, and a
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Early time interval:

At t = 13.40 s, the position was ⟨4.65, 3.06, −8

At t = 13.46 s, the position was ⟨4.72, 2.87, −9

Late time interval:

At t = 16.40 s, the position was ⟨10.77, 11.14,

At t = 16.46 s, the position was ⟨10.95, 11.65,

(a) In the early time interval, from t = 13.40 s to t = 1
mass of the Ping-Pong ball is 2.7 grams (2.7×10^{-3} kg).

$\vec{p}$ = ☐ kg · m/s

(b) In the late time interval, from t = 16.40 s to t = 16
your result as a vector.

$\vec{p}$ = ☐ kg · m/s

(c) In the time interval from t = 13.40 s (the start of th
time interval), what was the average net force acting on

$\vec{F}_{net}$ = ☐ N

```
momentum (initial) < 0.00315, -0.00855, -0.0405 >
momentum (final) < 0.0081, 0.02295, -0.0405 >
F=dp/dt= < 0.00165, 0.0105, 4.25585e-16 >
```

Run this program Share or export this pro

```
GlowScript 1.1 VPython
#HW2 Prob 8
scene.background=color.white
ri=vector(4.65,3.06,-8.45)
ti=13.40
rf=vector(4.72,2.87,-9.35)
tf=13.46
ball=sphere(pos=ri,rad=0.2,color=color.yellow)
ball.m=2.7e-3
deltar=rf-ri
deltat=tf-ti
v=deltar/deltat
p=ball.m*v
scene.pause('Click to proceed')
print("momentum (initial)",p)
pi=p
ri=vector(10.77,11.14,-54.35)
ti=16.40
rf=vector(10.95,11.65,-55.25)
tf=16.46
deltar=rf-ri
deltat=tf-ti
v=deltar/deltat
p=ball.m*v
scene.pause('Click to proceed')
print("momentum (final)",p)
deltap=p-pi
deltat=16.40-13.40
dp_dt=deltap/deltat
scene.pause('Click to proceed')
print("F=dp/dt=",dp_dt)
```

How to solve the projectile motion in a computer?

16. **0/6 points** MI4 2.4.021. [3219763] -

Use the approximation that $v \approx \vec{p}_f/m$ for each time step.

You throw a metal block of mass 0.20 kg into the air, and it leaves your hand at time $t = 0$ at location $\langle 0, 2, 0 \rangle$ m with velocity $\langle 2.5, 3.5, 0 \rangle$ m/s. At this low velocity air resistance is negligible. Using the iterative method shown in Section 2.4 with a time step of 0.05 s, calculate step by step the position and velocity of the block at $t = 0.05$ s, $t = 0.10$ s, and $t = 0.15$ s. (Express your answers in vector form.)

$\vec{x}(t = 0.05\text{ s}) =$ ✗ m

$\vec{v}(t = 0.05\text{ s}) =$ ✗ m/s

$\vec{x}(t = 0.10\text{ s}) =$ ✗ m

$\vec{v}(t = 0.10\text{ s}) =$ ✗ m/s

$\vec{x}(t = 0.15\text{ s}) =$ ✗ m

$\vec{v}(t = 0.15\text{ s}) =$ ✗ m/s

Iterative solution

- Calculate the net force $\vec{F}_{\text{net,now}}$ acting on the system
- Update momentum: $\vec{p}_{\text{future}} = \vec{p}_{\text{now}} + \vec{F}_{\text{net,now}}\Delta t$
- Update position: $\vec{r}_{\text{future}} = \vec{r}_{\text{now}} + \vec{v}_{\text{avg}}\Delta t$

repeat!

$$\vec{v}_{\text{avg}} \approx \vec{v}_f$$

$$\vec{v}_{\text{avg}} \approx \frac{\vec{v}_i + \vec{v}_f}{2}$$

How to solve the projectile motion in a computer?

16. **0/6 points** MI4 2.4.021. [3219763] -

Use the approximation that $v \approx \vec{p}_f/m$ for each time step.

You throw a metal block of mass 0.20 kg into the air, and it leaves your hand at time $t = 0$ at location $\langle 0, 2, 0\rangle$ m with velocity $\langle 2.5, 3.5, 0\rangle$ m/s. At this low velocity air resistance is negligible. Using the iterative method shown in Section 2.4 with a time step of 0.05 s, calculate step by step the position and velocity of the block at $t = 0.05$ s, $t = 0.10$ s, and $t = 0.15$ s. (Express your answers in vector form.)

$\vec{x}(t = 0.05\text{ s}) =$ ✗ m

$\vec{v}(t = 0.05\text{ s}) =$ ✗ m/s

$\vec{x}(t = 0.10\text{ s}) =$ ✗ m

$\vec{v}(t = 0.10\text{ s}) =$ ✗ m/s

$\vec{x}(t = 0.15\text{ s}) =$ ✗ m

$\vec{v}(t = 0.15\text{ s}) =$ ✗ m/s

Run this program **Share or export this progr**

```
GlowScript 1.1 VPython
#HW2 Prob 16
scene.background=color.yellow

t=0
ball=sphere(pos=vector(0,2,0), rad=0.1, color=color.blue)
ball.vel=vector(2.5,3.5,0)
ball.m=0.2
ball.p=ball.m*ball.vel


deltat=0.05
g=9.8

while t<=0.15:
    scene.pause('Click to proceed')
    fnet=vector(0,-ball.m*g,0)
    ball.p=ball.p + fnet*deltat
    vavg=ball.p/ball.m
    print("time",t+deltat,"vavg",vavg)
    ball.pos=ball.pos + vavg*deltat
    print("time",t+deltat,"position",ball.pos)
    t=t+deltat
```

Physics 2211: *Matter and Interactions*

How to solve the projectile motion in a computer?

18. Question Details MI4 2.4.023. [3219765]

A soccer ball of mass 0.40 kg is rolling with velocity $\langle 0, 0, 3.0\rangle$ m/s, when you kick it. Your kick delivers an impulse of magnitude 1.2 N · s in the $-x$ direction. The net force on the rolling ball, due to the air and the grass, is 0.20 N in the direction opposite to the direction of the ball's momentum. Using a time step of 0.5 s, find the position of the ball at a time 1.5 s after you kick it, assuming that the ball is at the origin at the moment it is kicked. Use the approximation $\vec{v}_{avg} \approx \vec{p}_f/m$. (Express your answer in vector form.)

$\vec{r}_f$ = ✗ $< -3.97, 0, 3.97 >$ m

Additional Materials

Section 2.4

```
GlowScript 1.1 VPython
#HW2 Prob 18
scene.background=color.yellow

t=0
ball=sphere(pos=vector(0,0,0), rad=0.1, color=color.blue)
ball.vel=vector(0,0,2.0)
ball.m=0.5
ball.p=ball.m*ball.vel
impulse=vector(-1.8,0,0)
ball.p=ball.p+impulse
print("momentum after cick",ball.p)
ballpunitary=ball.p/mag(ball.p)
print("momentum after cick",ballpunitary)
Ffrictionmag=0.26
Ffriction=-ballpunitary*Ffrictionmag
print("momentum after cick",Ffriction)

deltat=0.5

while t<1.5:
    scene.pause('Click to proceed')
    ball.p=ball.p+deltat*Ffriction
    vavg=ball.p/ball.m
    ball.pos=ball.pos+deltat*vavg
    print("at time",t+deltat,"position is:",ball.pos)
    t=t+deltat
```