Physics 131- Fundamentals of Physics for Biologists I

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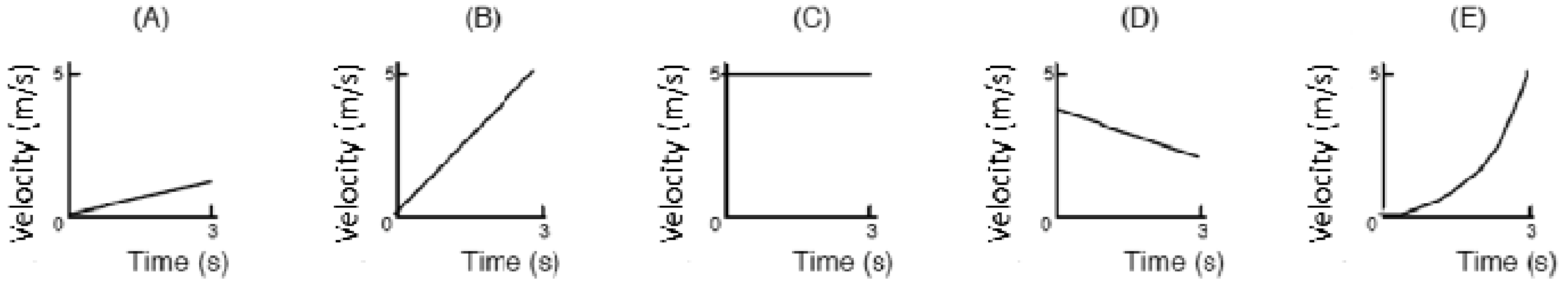
Outline

- Quiz 4
- Newton's Laws
- What's a force?
- Newton's Laws
- Kinds of Forces

Quiz 3: Average 8.2/10

Quiz 3

1. Five objects (A) through (E) move according to the velocity versus time graphs shown below.

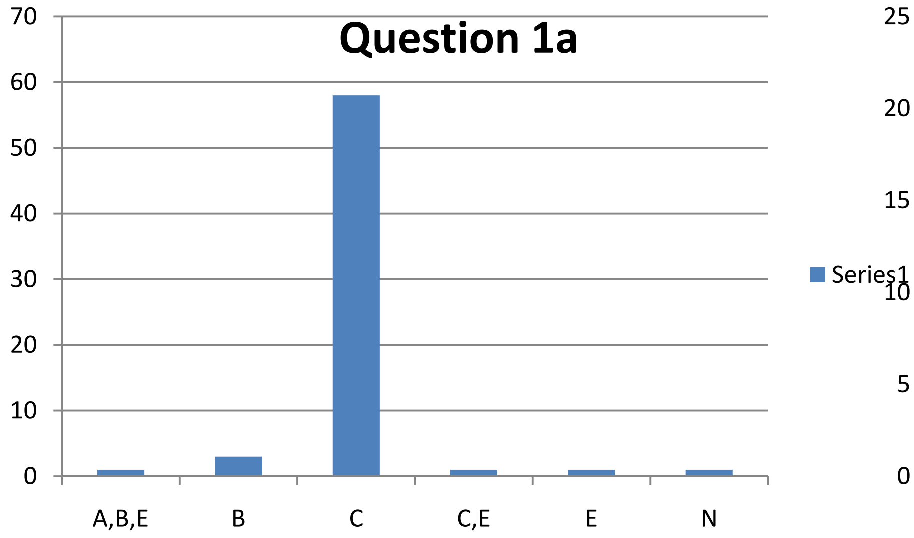


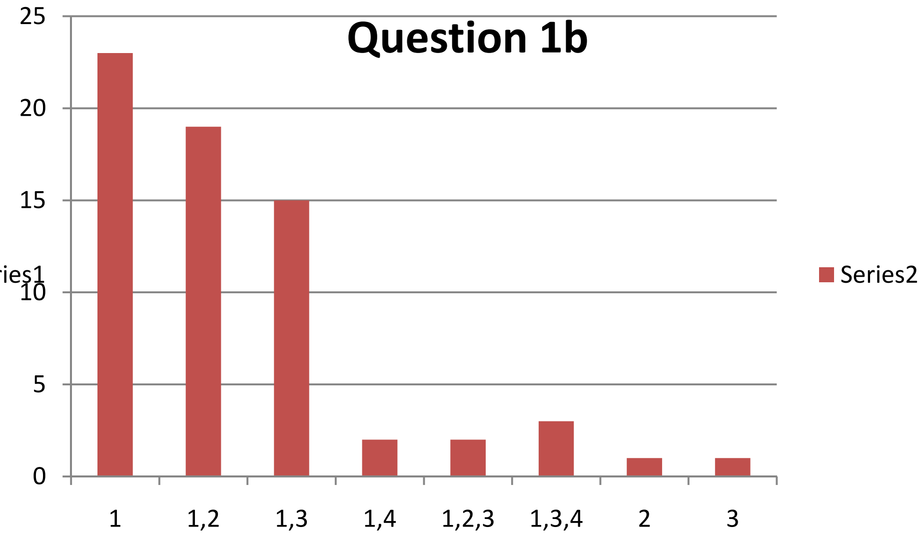
1a (2 pts) Which object has moved the furthest from its starting position in 3 seconds?

1b (2 pts) Comparing the objects moving according to graphs (B) and (E), which of the following is true:

1. Both objects have the same velocity at t=3 seconds
2. Both objects have the same average velocity
3. Both objects have the same average acceleration
4. Both objects have the same acceleration at t=3 seconds

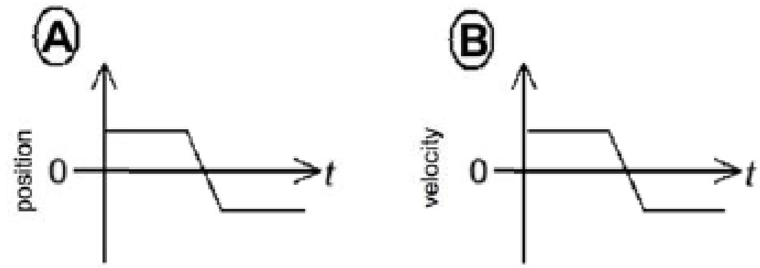
Quiz 3


Question 1a
70
60
50
40
30
20
10
0
A,B,E
B
C
C,E
E
N
Series1


Question 1b
25
20
15
10
5
0
1
1,2
1,3
1,4
1,2,3
1,3,4
2
3
Series2

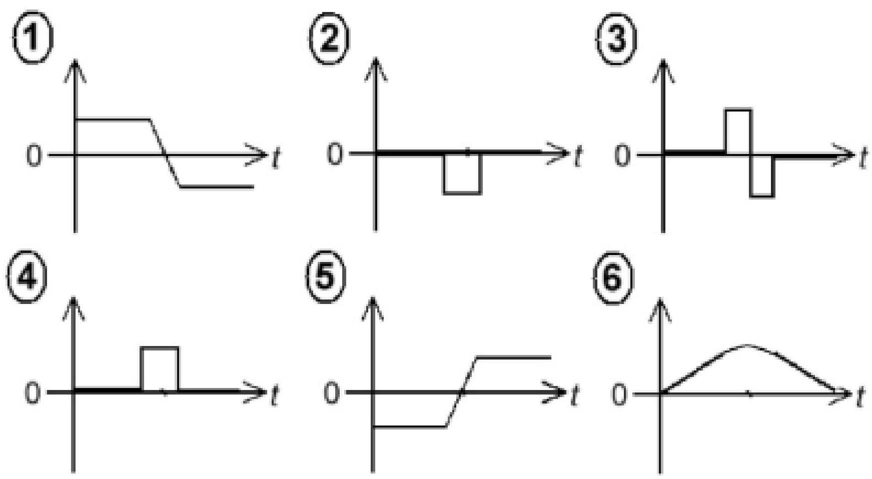
Quiz 3

2. An object's motion is restricted to one dimension along the distance axis.
In case A, the object's location is described by the **position** graph labeled "A" below.
In case B, the object moves as described by the **velocity** graph labeled "B" below.

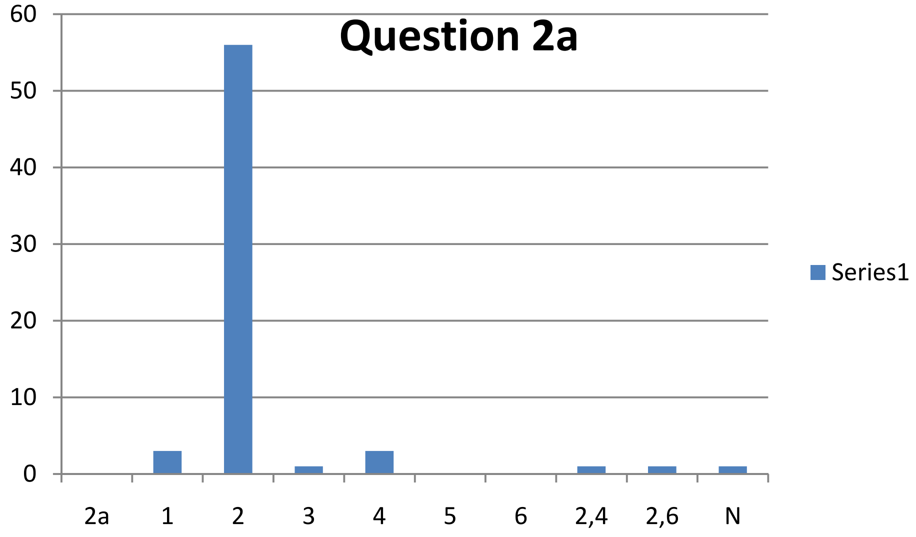


From the questions below, select which of the graphs below (labeled 1-6) could be correct if the proper vertical scale were chosen? If more than one graph is correct, give them all. If none is correct, write N.

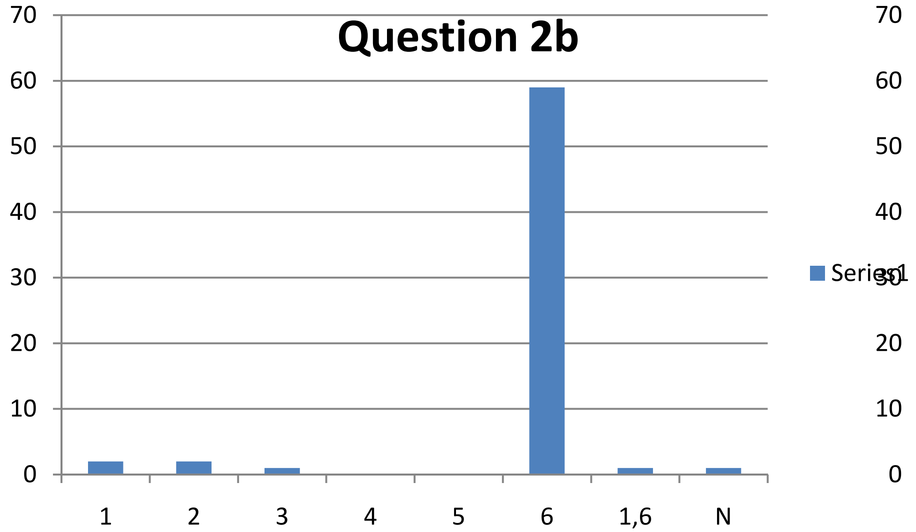
a. **(2 pts)** Which graph could represent the velocity graph for case A?
b. **(2 pts)** Which graph could represent the position graph for case B?
c. **(2 pts)** Which graph could represent the acceleration graph for case B?



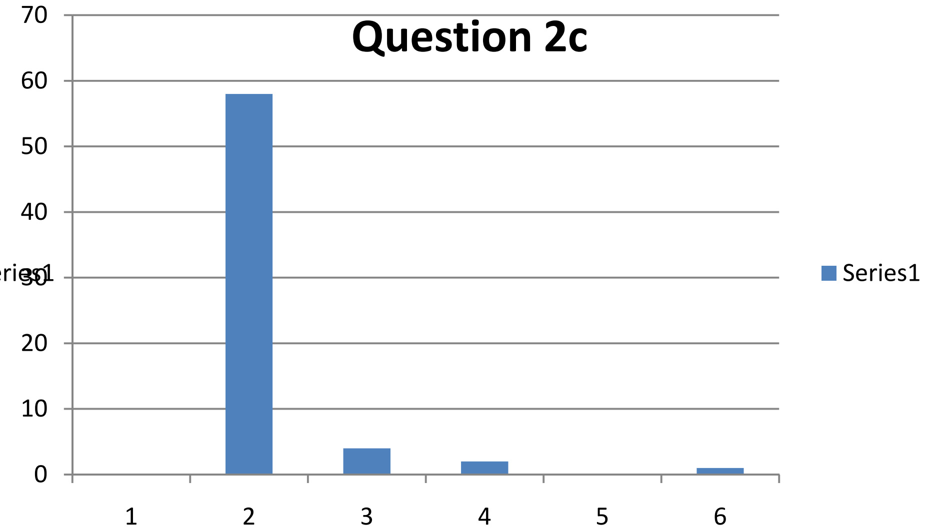
Quiz 3



Question 2a
60
50
40
30
20
10
0
2a
1
2
3
4
5
6
2,4
2,6
N
Series1



Question 2b
70
60
50
40
30
20
10
0
1
2
3
4
5
6
1,6
N
Series1



Question 2c
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Series1

Kinematics and Dynamics

- Kinematics: Describing motion
  - Acceleration
- Dynamics: What causes motion
  - Forces and Newton's laws

Conceptual ideas underlying Newton's Laws: 1

- Objects respond only to influences acting upon them at the instant that those influences act. (**Object egotism**)

- All outside effects on an object being equal, the object maintains its velocity (including direction). The velocity could be zero, which would mean the object is at rest. (**Inertia**)

- Every change in velocity an object experiences is caused by the object interacting with some other object – forces. (**Interactions**)

Conceptual ideas underlying Newton's Laws: 2

- If there are a lot of different objects that are interacting with the object we are considering, the overall result is the same as if we add up all the forces as vectors and produce a single effective force -- the *net force*. (**Superposition**)
- When one object exerts a force on another, that force is <u>shared</u> over all parts of the structure of the object. (**Mass**)
- Whenever two objects interact, they exert forces on each other. (**Reciprocity**)

Foothold principles: Newton's Laws

- Newton 0:
  – An object responds **only** to the forces it feels and only at the instant it feels them.
- Newton 1:
  – An object that feels a net force of 0 keeps moving with the same velocity (which may = 0).
- Newton 2:
  – An object that is acted upon by other objects changes its velocity according to the rule

$$\vec{a}_A = \vec{F}_A^{net} / m_A$$

- Newton 3:
  – When two objects interact the forces they exert on each other are equal and opposite.

$$\vec{F}_{A\to B}^{type} = -\vec{F}_{B\to A}^{type}$$

Newton's 2nd Law (conceptual form)

$$\Delta v = \mathscr{I} / m$$

$$\Delta x = v \Delta t$$

- Where
  - $\tilde{I}$ is the "impulse" (something delivered to the object by another object touching it)
  - m is the "mass" (a property of the object that says how many bowling balls it is equivalent to)

A More Familiar Form

- If the object that is causing the change of velocity by exerting a force for a certain (small) amount of time.

- Then we get

$$\mathscr{I} = F\Delta t$$

$$\Delta v = \left(\frac{F}{m}\right)\Delta t \qquad \frac{dv}{dt} = \frac{F}{m}$$

$$\Delta x = v\,\Delta t \qquad \frac{dx}{dt} = v$$

$$\longrightarrow \quad \longrightarrow \quad a = F/m$$

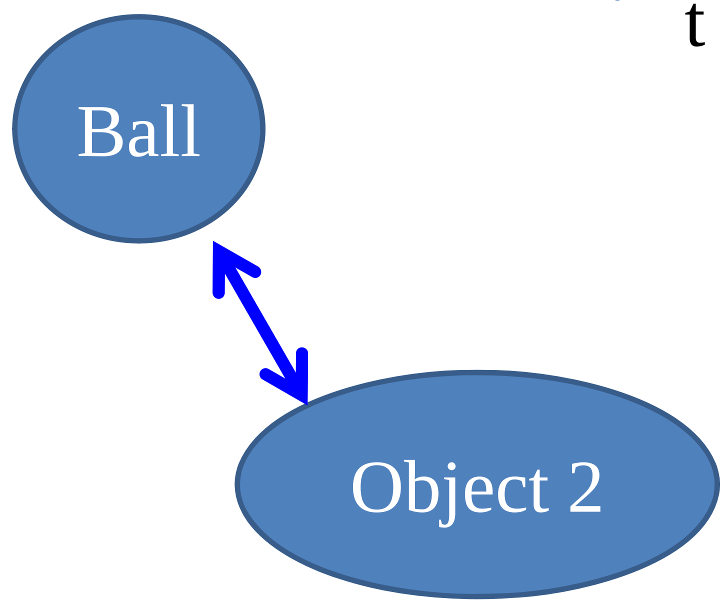
Models of Systems

- The Newtonian principles create the framework: now we need to build models of specific situations.
- The SS specifies a basic model – objects and interactions.
- Then we have to specify the properties of the objects (mass, structure) and make models of the interactions. These are *forces*.

What causes Motion?

Whose motion we are describing?

An object of interest (the ball)

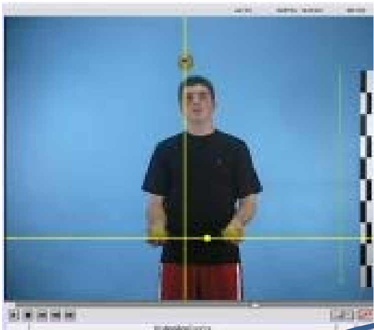


What Causes its motion?

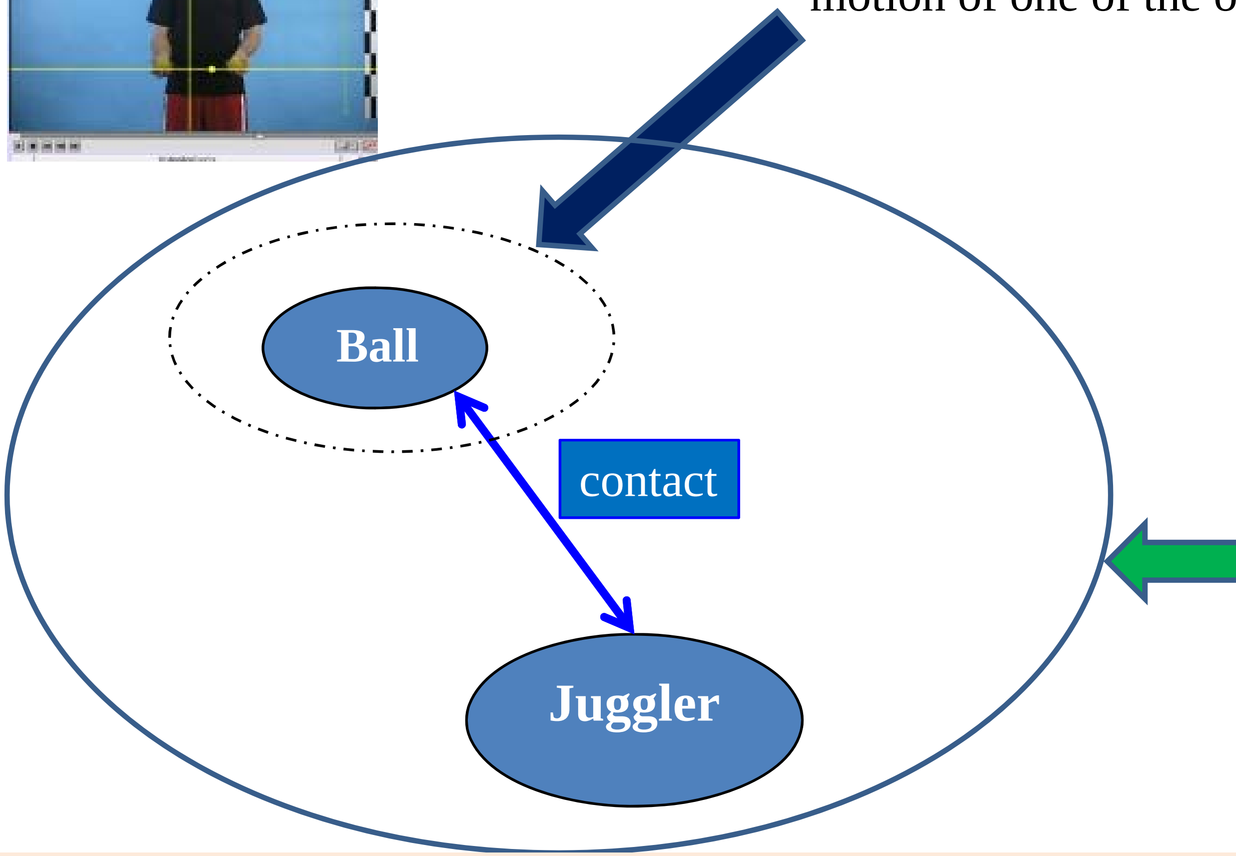
Other objects interacting with ball

Draw a System Schema that would be appropriate for talking about what causes the motion of the ball.

System Schema



We want to understand & calculate what causes the motion of one of the objects, **the ball.**

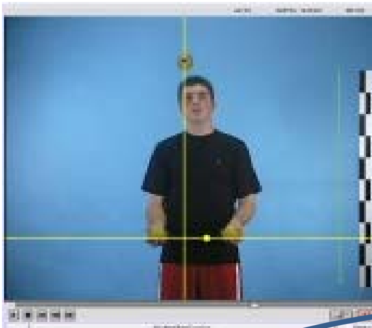


The Ball interacts with other objects, it is part of a system

How can we take all of these concepts into consideration when we are dealing with more than two objects?

How exactly would this principle be applied to … living organisms?

System Schema



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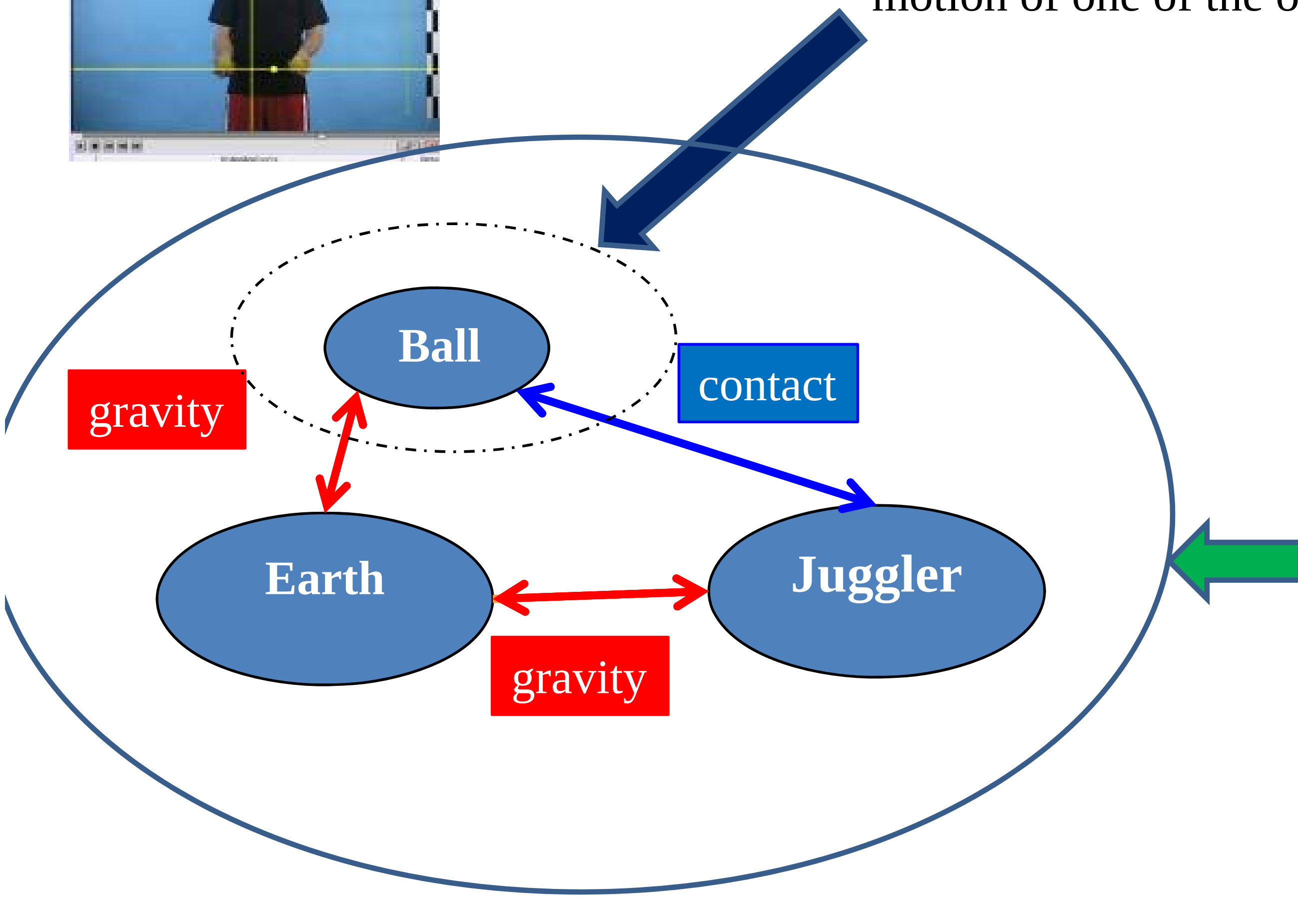


The Ball interacts with other objects, it is part of a system

In order to go further, we have to model the interactions. One way is with forces.

Reading question

- Since the equation $a = F/m$ is not the definition of acceleration, then is $F = ma$ not the definition of force? If not, what is the definition of force?

Technical term alert: What’s a Force?

- The “*F*” in Newton’s law is an expression of the idea:
  - When two objects interact they do something to each other that tends to change the other’s velocity.
- Although the technical term for this is “force” it is different from the common speech idea of force.
  - It is an interaction between two objects.
  - It only occurs via contact or by the non-touching examples of gravity, electricity, and magnetism.

Technical term alert: What's a "Force"?

Forces are connected to acceleration – Newton's 2nd law

$$\vec{a} = \vec{F}^{net} / m$$

Even if we have a new name for it, what the &*$#% is it?

- How can we "define" a force?
- What would a definition look like?
- Process:
  - Define some force that can set a quantitative measurable standard (spring)
  - Measure object's masses by seeing how much a standard force accelerates them.
  - Create models of new forces (as, perhaps, functions of position) by seeing how they accelerate objects.
  - Use our force models to predict motions.
  - If we quickly stop having to add new forces we have a stable structure.

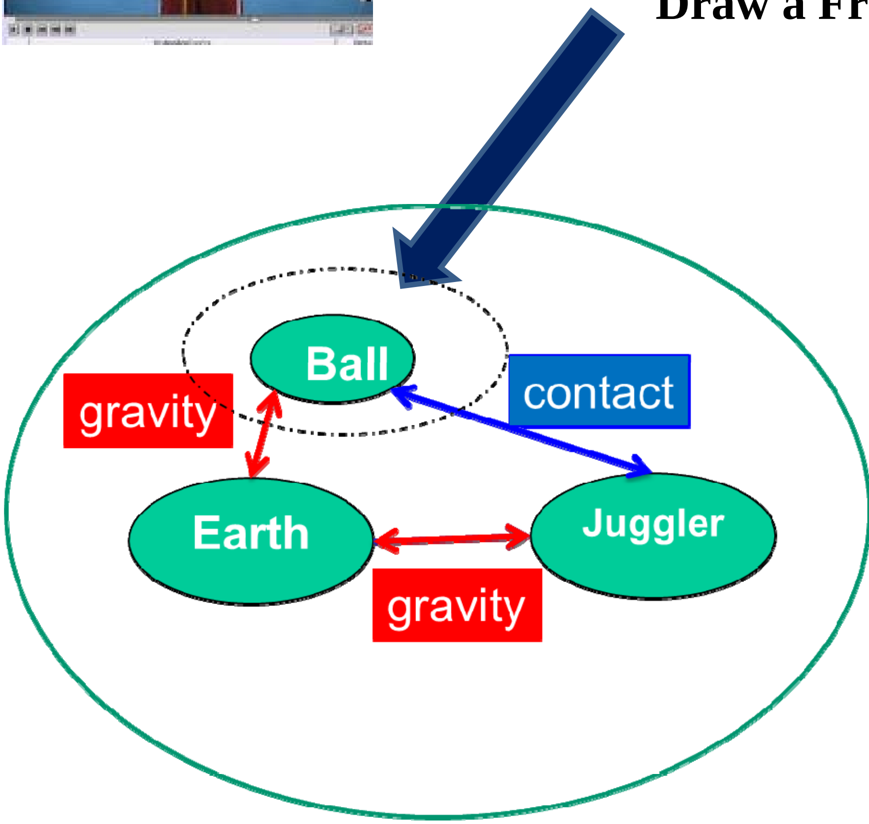
Conceptual ideas 1-3 underlying Newton's Laws

1. Every change in velocity an object experiences is caused by the object interacting with some other object – **forces**. (Interactions)
2. Objects respond only to forces ***acting upon them*** and they do so only at the instant that those forces act. (Object egotism) [Newton 0]
3. If there are a lot of different objects that are interacting with the object we are considering, the overall result is the same as if we add up all the forces as vectors and produce a single effective force -- the **net force**. (Superposition)

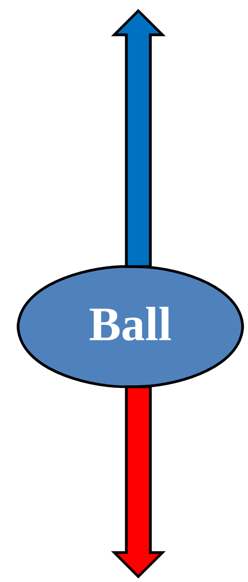
The Free Body Diagram

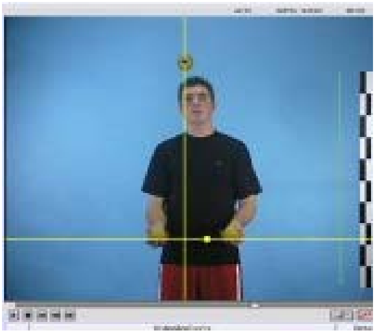
We want to understand & calculate what causes the motion of one of the objects, **the ball.**

Draw a Free Body Diagram for Ball

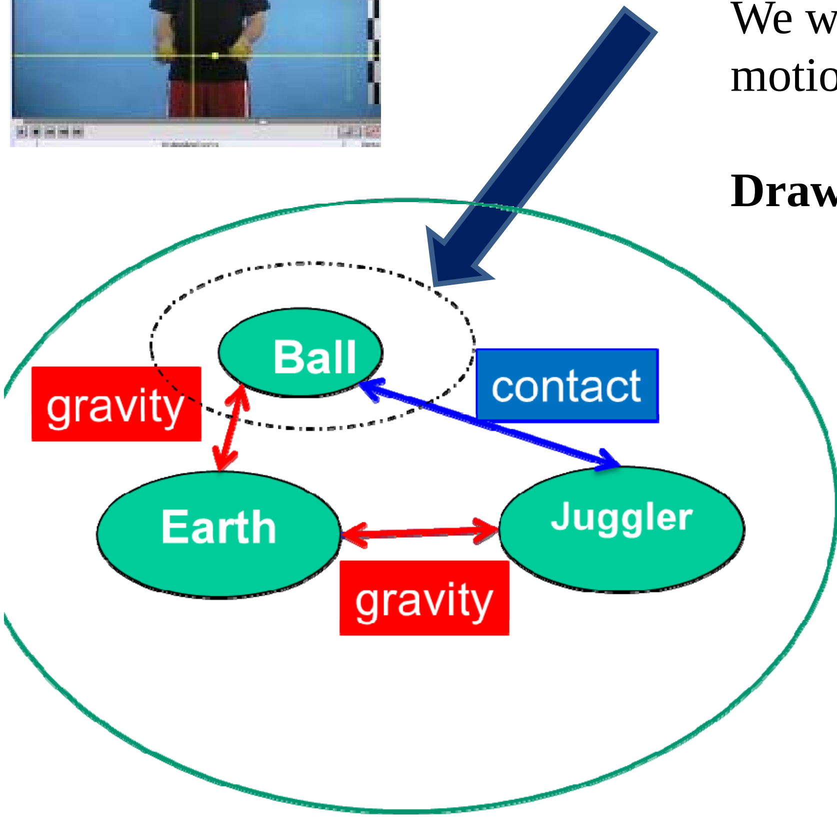


$$\vec{F}^{\,net} = ??$$



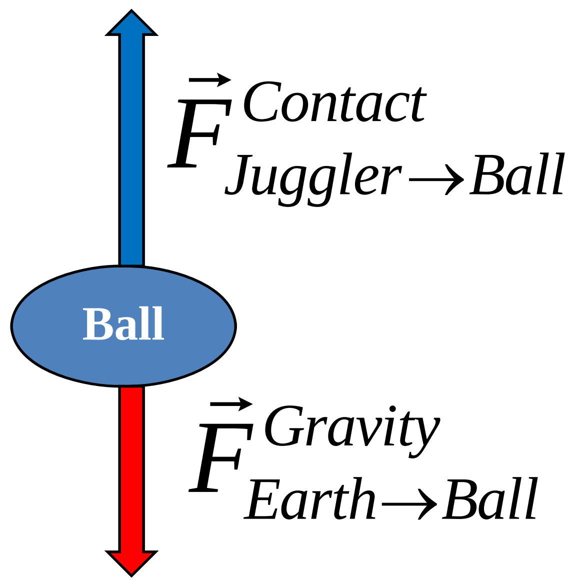


The Free Body Diagram



We want to understand & calculate what causes the motion of one of the objects, **the ball.**

Draw a Free Body Diagram for Ball

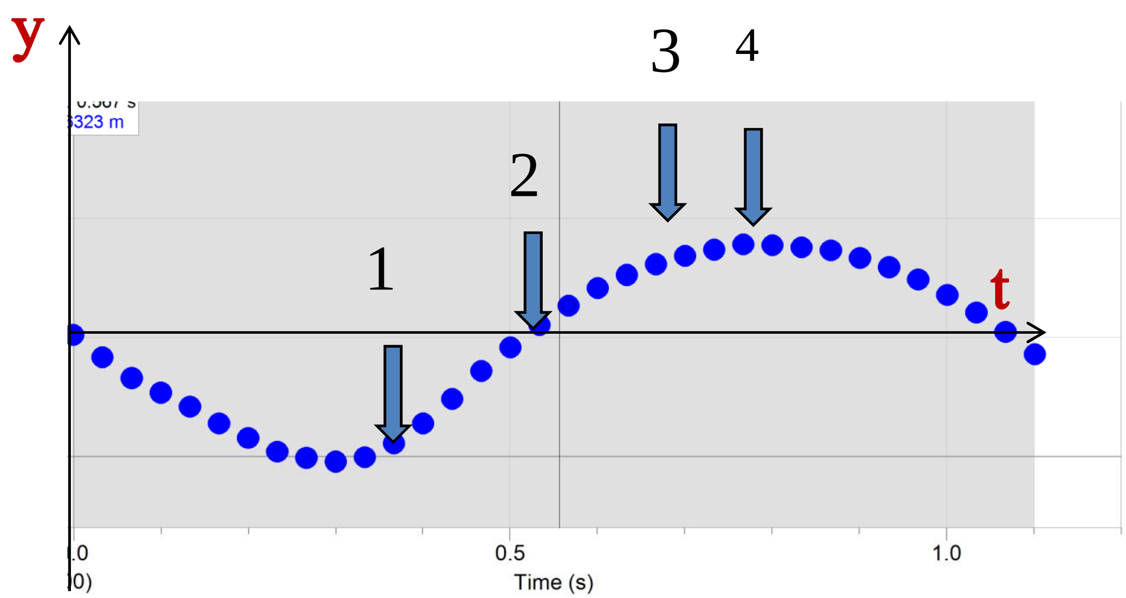


$$\vec{F}^{net} = \vec{F}^{Gravity}_{Earth \to Ball} + \vec{F}^{Contact}_{Juggler \to Ball}$$

Net force: Sum all forces; use direction BALL feels (object egotism)

Looking at the position vs time graph, where does the juggler let go of the ball?

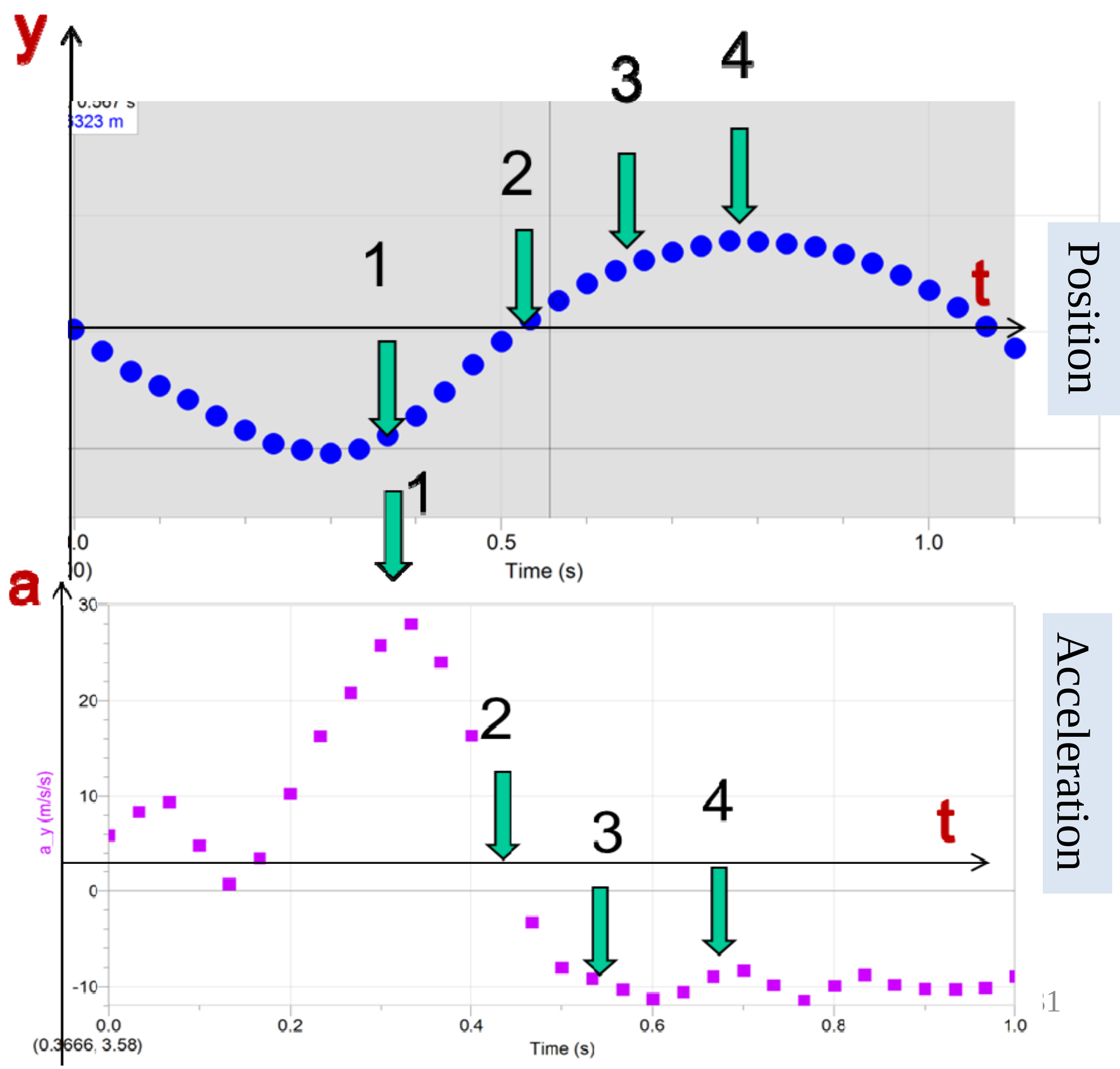
1. At 1
2. At 2
3. At 3
4. At 4
5. Before 1
6. After 4

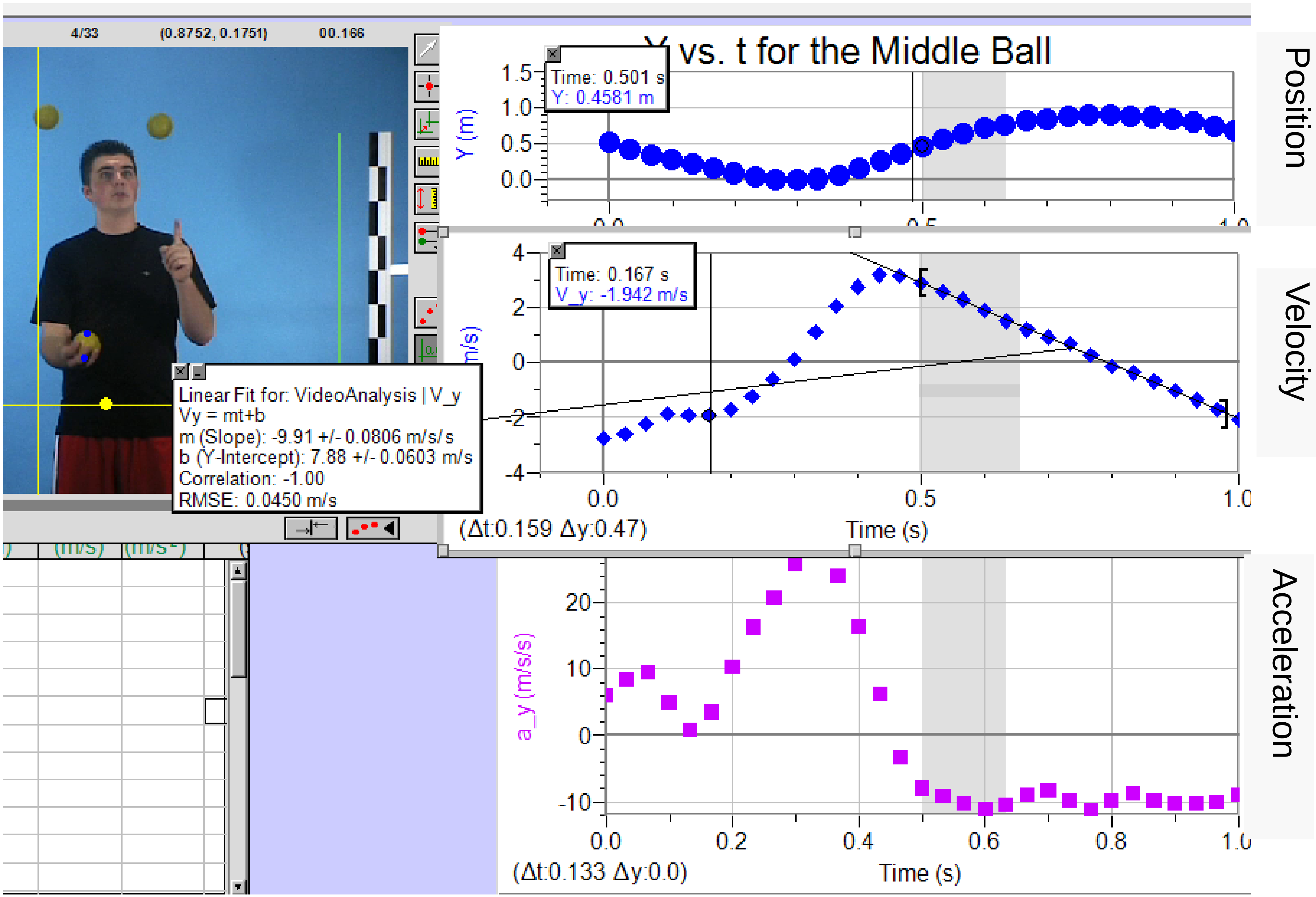


When does the juggler no longer touch the ball?

- Explain your choice on ***whiteboard (TA & LA)***
- *If all in a group agree -> convince other groups*

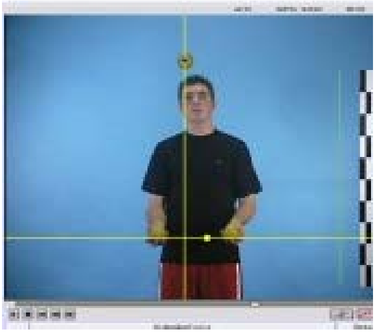
1. At 1
2. At 2
3. At 3
4. At 4
5. Before 1
6. After 4

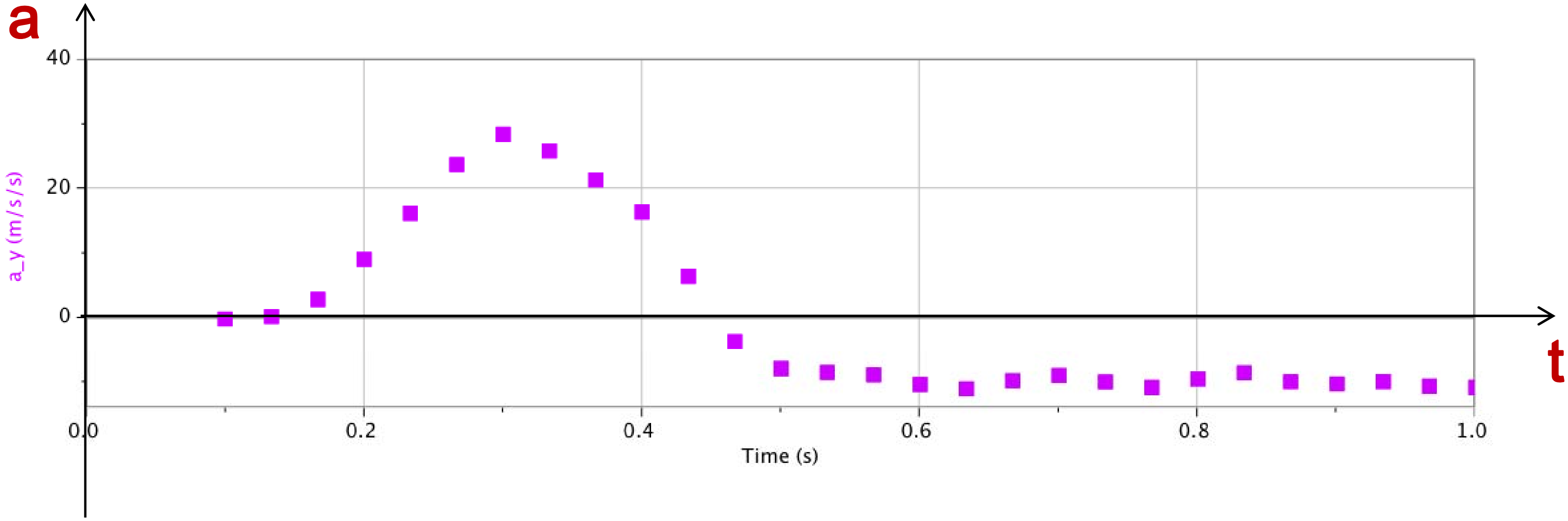




4/33
(0.8752, 0.1751)
00.166
Y vs. t for the Middle Ball
Time: 0.501 s
Y: 0.4581 m
Y (m)
Position
Time: 0.167 s
V_y: -1.942 m/s
Velocity
Linear Fit for: VideoAnalysis | V_y
Vy = mt+b
m (Slope): -9.91 +/- 0.0806 m/s/s
b (Y-Intercept): 7.88 +/- 0.0603 m/s
Correlation: -1.00
RMSE: 0.0450 m/s
(Δt:0.159 Δy:0.47)
Time (s)
a_y (m/s/s)
Acceleration
(Δt:0.133 Δy:0.0)
Time (s)

Draw the force vs. time graph





Conceptual ideas 4-7 underlying Newton's Laws

4. When one *solid* object exerts a force on another, that force is <u>shared</u> over all parts of the object. (Mass)
5. The acceleration felt by an object at a given instant is the net force on the object at that instant divided by the object's mass. [Newton 2]
6. All outside effects on an object canceling out (net force of zero), the object maintains its velocity (including direction). The velocity could be zero, which would mean the object is at rest. (Inertia) [Newton 1]
7. Whenever two objects interact, they exert forces on each other. (Reciprocity) [Newton 3]

The Earth pulls on the ball. Does the ball pull on the Earth?

A. No

B. Yes but the force the ball exerts on the earth is tiny compared to the force the earth exerts on the ball

C. Yes it pulls up the earth with the same force as the earth pulls down

Which of the following representations show Newton’s third law force pairs?

A. System Schema
B. Free Body Diagram
C. Both System Schema and Free Body Diagram
D. Neither

Newton's Laws

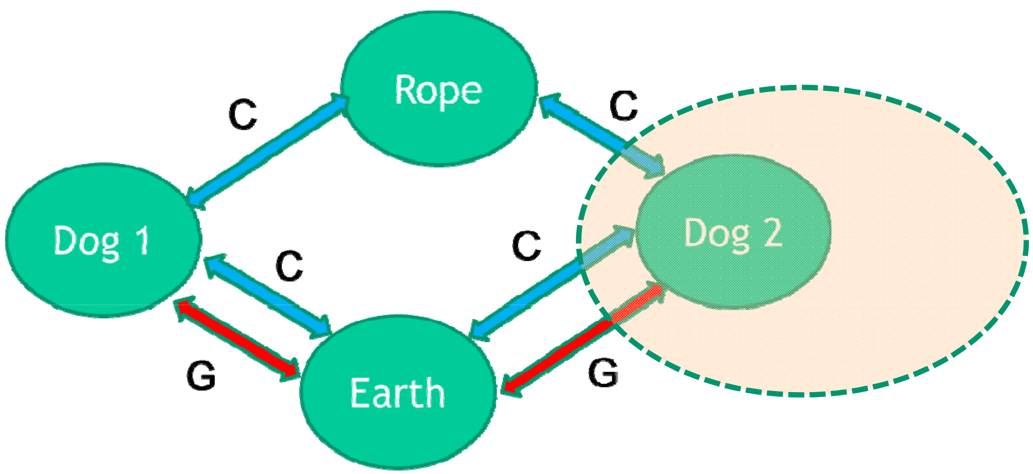
1. All outside effects on an object canceling out ("*net* force of zero"), the object maintains its velocity (including direction). The velocity could be zero, which would mean the object is at rest. (Inertia) [Newton 1]
2. The acceleration felt by an object (at a given instant) is the net force on the object at that instant divided by the object's mass. [Newton 2]

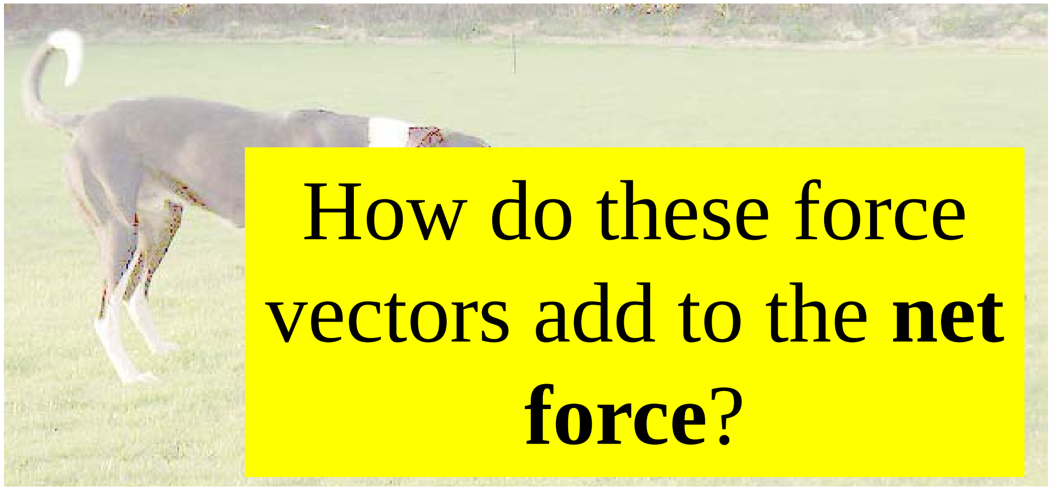
$$\vec{a} = \vec{F}^{net} / m$$

3. Whenever two objects interact, the forces they exert on each other are equal in magnitude and opposite in direction. (Reciprocity) [Newton 3]

Is it possible to include all the forces in schema? Since there are so many things going around on Earth, it can't right?

System Schema



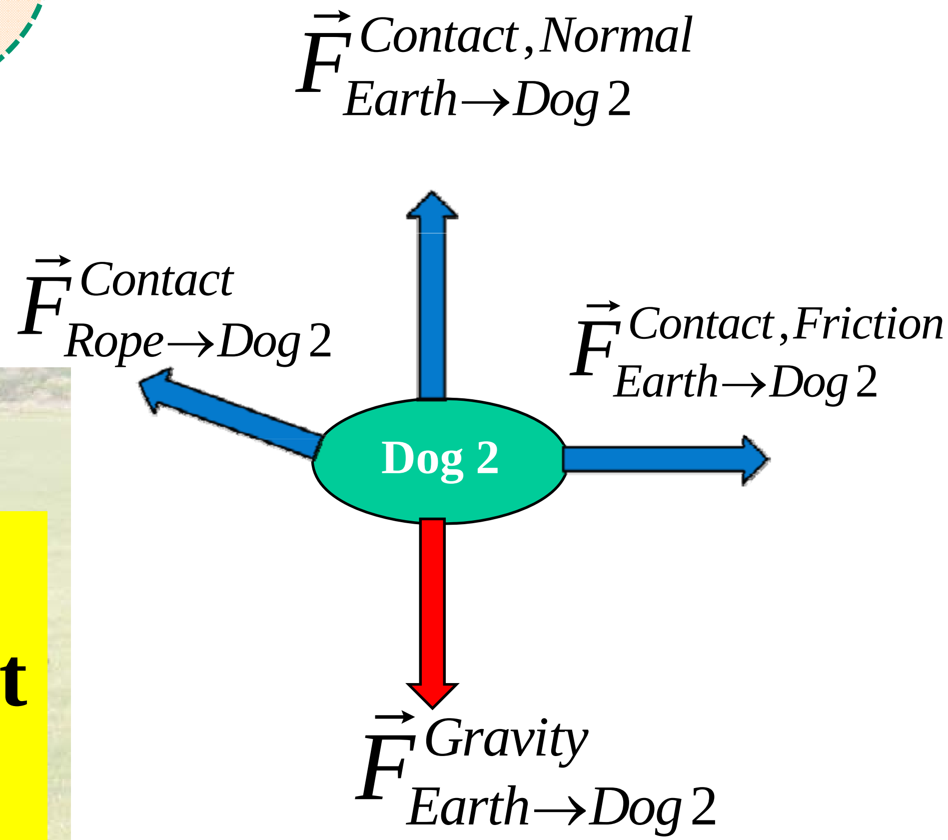


How do these force vectors add to the **net force**?

Free body diagram: dog 2

Provides information about:

- All forces exerted on the dashed circle (here: Dog 2)
- Magnitude of the forces
- Direction of the forces



Review of Vectors
(2-dimensional coordinates)

- We have 2 directions to specify. We must
  - Choose a reference point (origin)
  - Pick 2 perpendicular axes (x and y)
  - Choose a scale
- We specify our x and y directions by drawing little arrows of unit length in their positive direction.

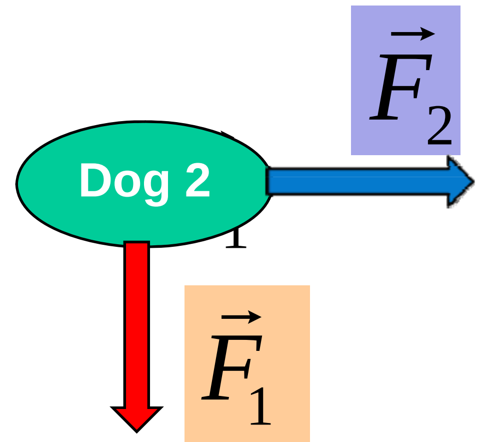
$$\hat{i},\ \hat{j}$$

- A force vector is written

$$\vec{F} = F_x\hat{i} + F_y\hat{j}$$

Adding Forces

$$\vec{F} = \vec{F}_1 + \vec{F}_2$$



We define the sum of two vectors as if they were successive displacements.

Adding Vectors Head to Tail