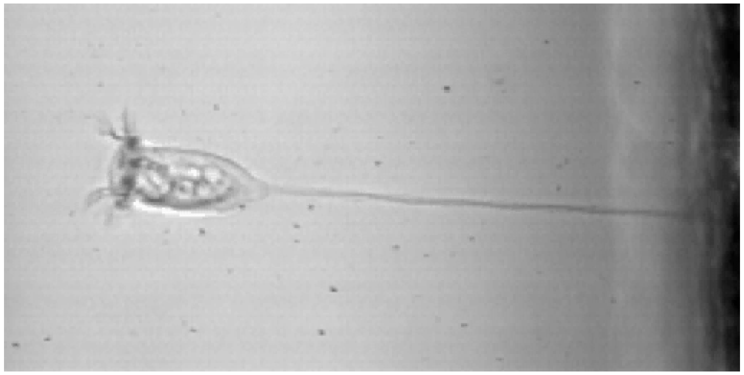
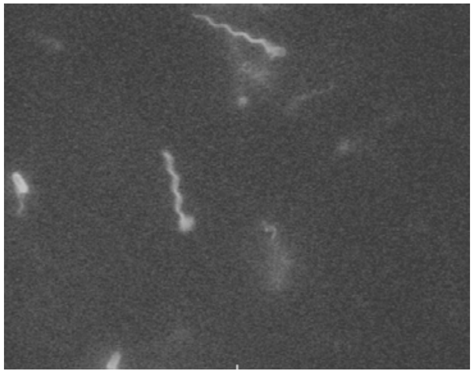
Physics 131- Fundamentals of Physics for Biologists I

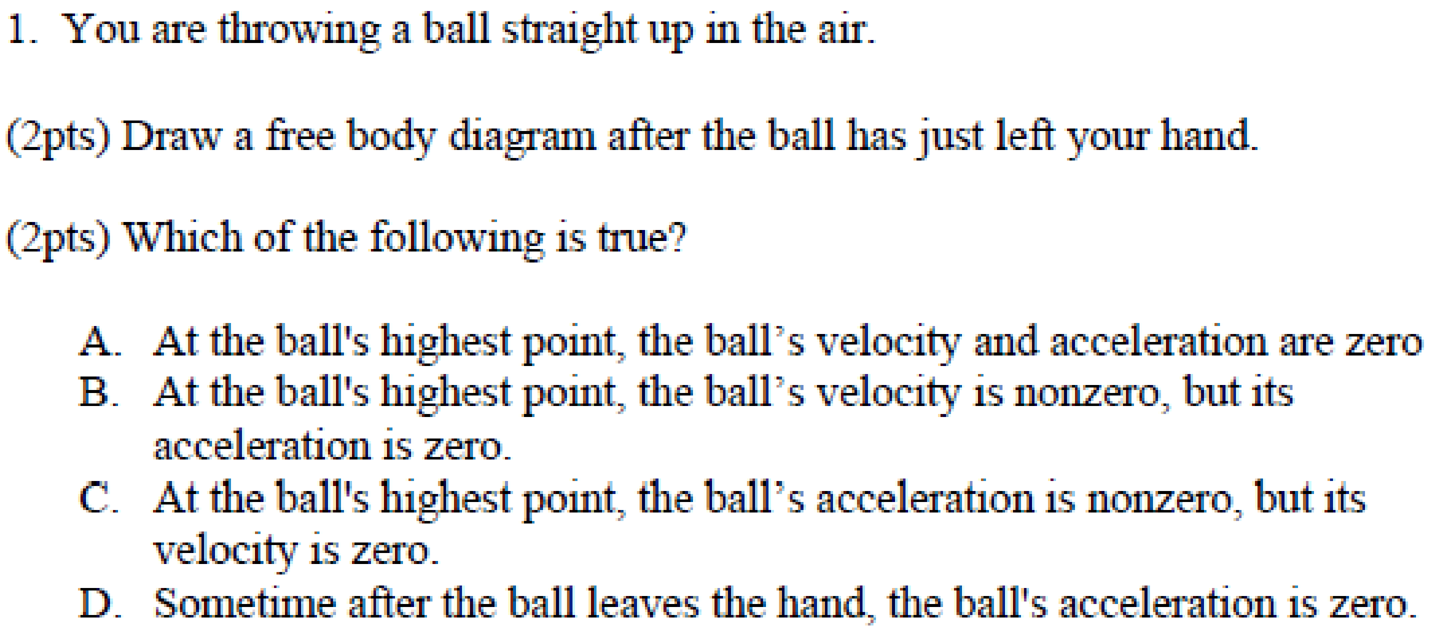
Professor: Arpita Upadhyaya

- Quiz 4 review
- Newton's Laws
- Kinds of Forces





Quiz 4 review

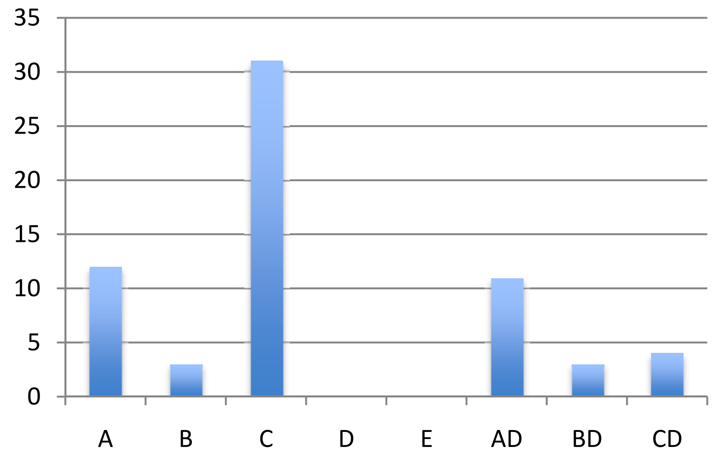


1. You are throwing a ball straight up in the air.

(2pts) Draw a free body diagram after the ball has just left your hand.

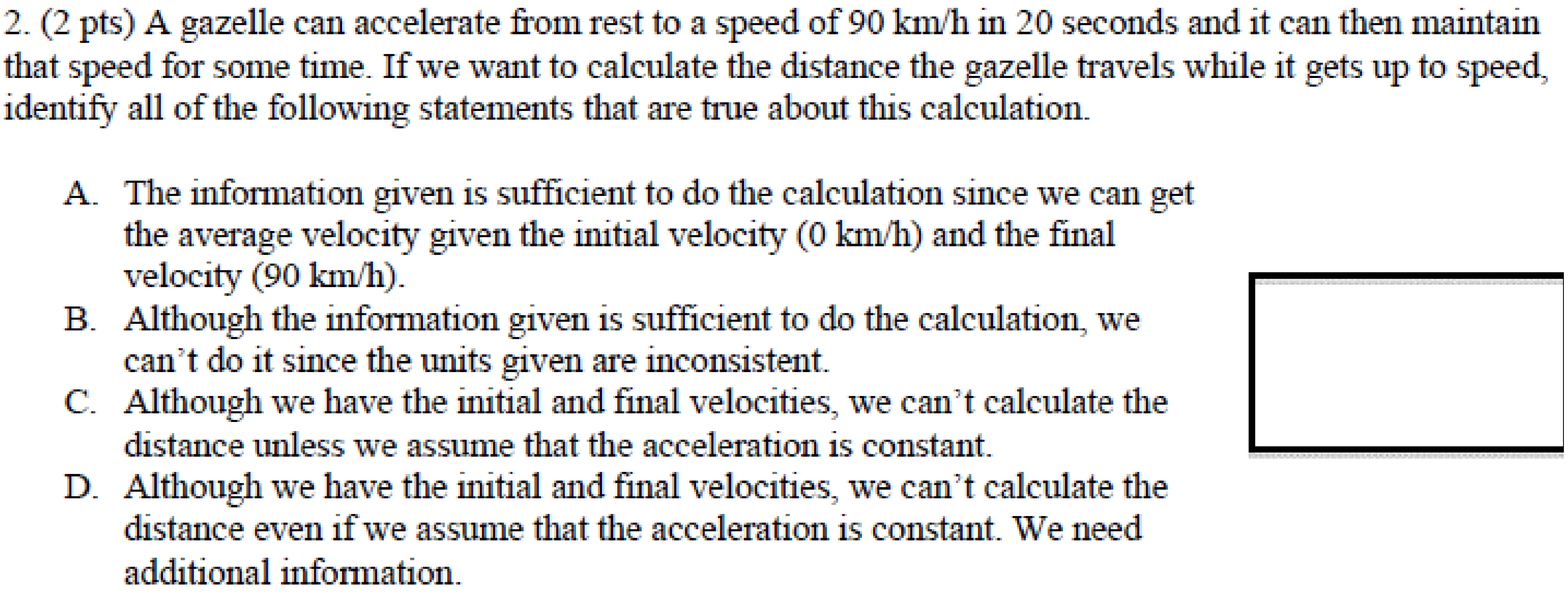
(2pts) Which of the following is true?

A. At the ball's highest point, the ball's velocity and acceleration are zero
B. At the ball's highest point, the ball's velocity is nonzero, but its acceleration is zero.
C. At the ball's highest point, the ball's acceleration is nonzero, but its velocity is zero.
D. Sometime after the ball leaves the hand, the ball's acceleration is zero.



QUESTION 1.2

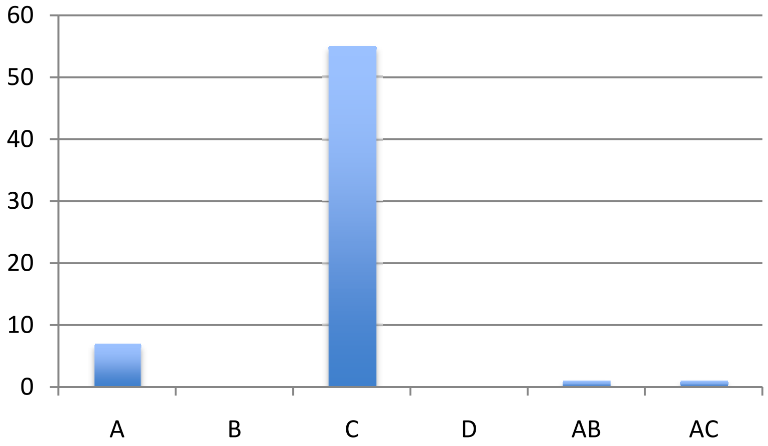
Quiz 4 review



2. (2 pts) A gazelle can accelerate from rest to a speed of 90 km/h in 20 seconds and it can then maintain that speed for some time. If we want to calculate the distance the gazelle travels while it gets up to speed, identify all of the following statements that are true about this calculation.

A. The information given is sufficient to do the calculation since we can get the average velocity given the initial velocity (0 km/h) and the final velocity (90 km/h).
B. Although the information given is sufficient to do the calculation, we can't do it since the units given are inconsistent.
C. Although we have the initial and final velocities, we can't calculate the distance unless we assume that the acceleration is constant.
D. Although we have the initial and final velocities, we can't calculate the distance even if we assume that the acceleration is constant. We need additional information.

QUESTION 2



Quiz 4 review

3. A trapper is camping out in the winter near a frozen lake. He needs to drag his loaded sled across the lake to town. The surface of the lake is quite smooth and slippery (so the friction from the ice on his sled is very small). but he has studded boots with nails driven through the sole so he can walk across the ice without slipping. Answer the following questions about his progress across the lake.

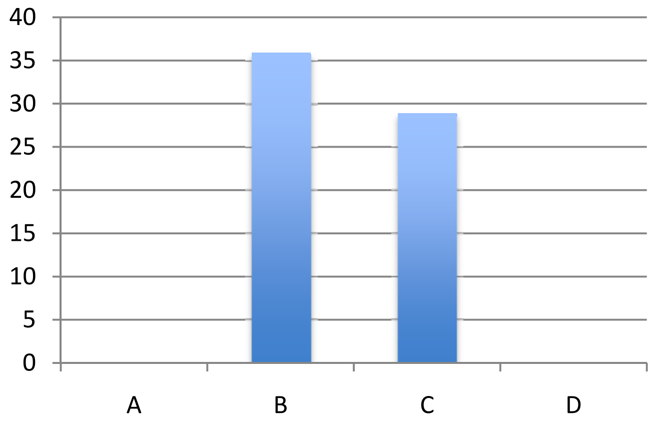
3.1 (2pts) He wants to get the sled up to a reasonable speed with the speed increasing at a constant rate. He should

A. Pull with a decreasing force
B. Pull with a constant force
C. Pull with an increasing force
D. Not pull at all

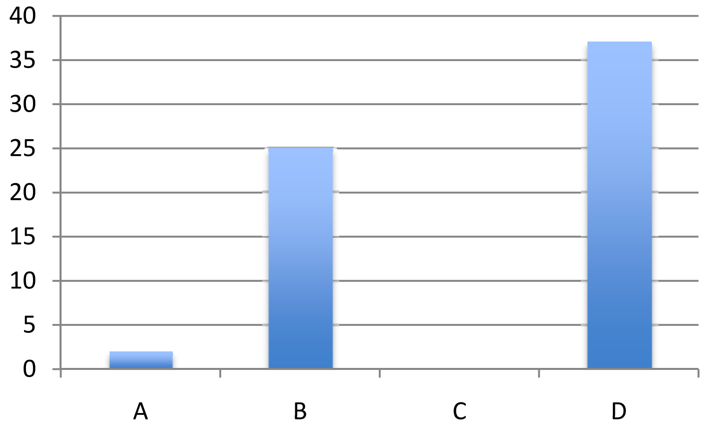
3.2 (2 pts) Once the sled is moving at a reasonable pace, in order to keep the sled moving at this pace he needs to

A. Pull with a decreasing force
B. Pull with a constant force
C. Pull with an increasing force
D. Not pull at all

QUESTION 3.1



QUESTION 3.2



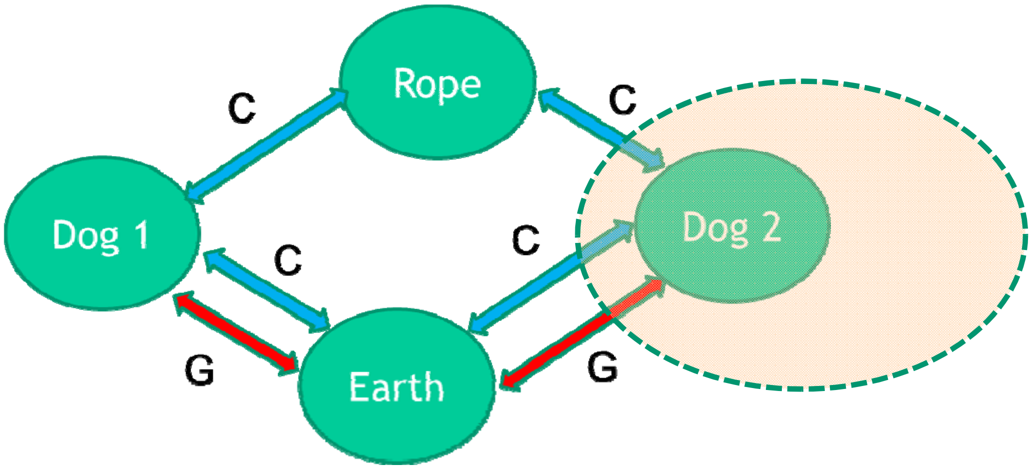
Newton's Laws

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

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

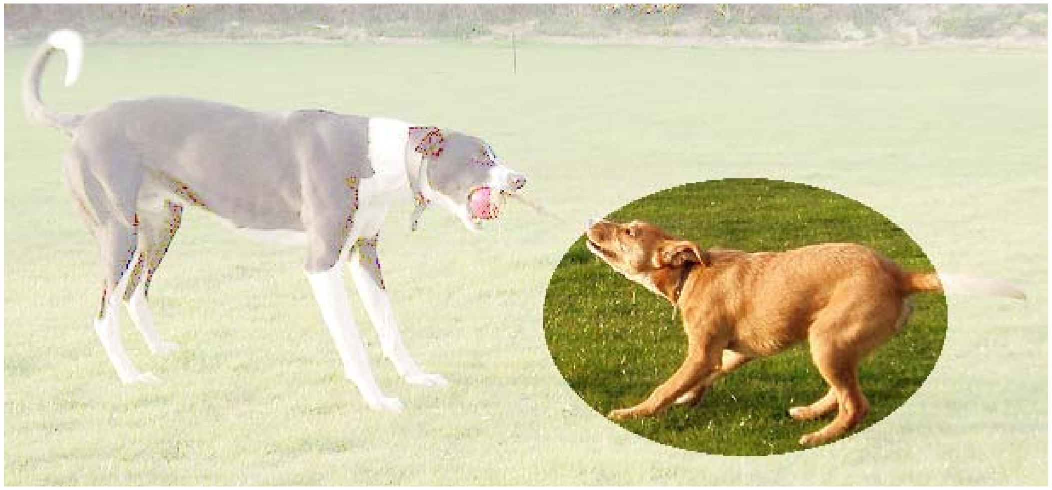
$$\vec{F}^{type}_{A\to B} = -\vec{F}^{type}_{B\to A}$$

System Schema

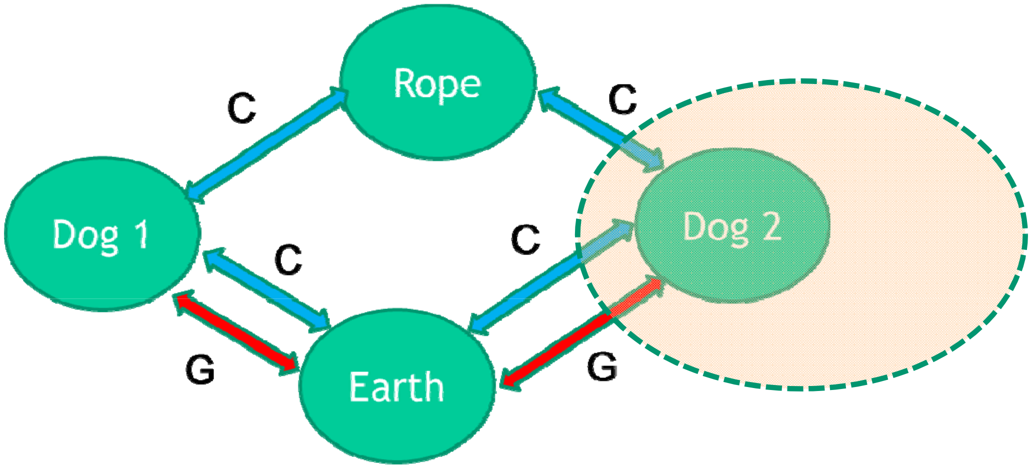


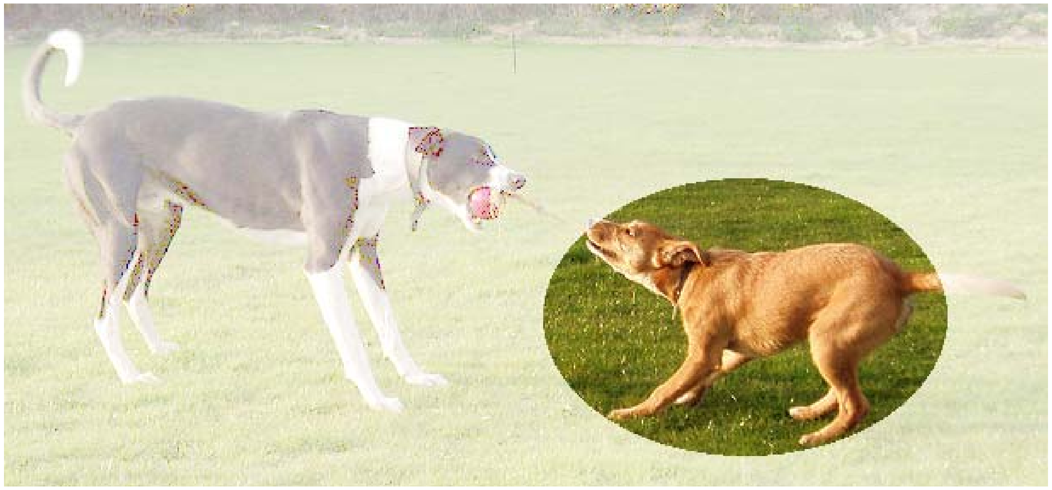
Draw the free body diagram for dog 2

Dog 2



System Schema





Free body diagram: dog 2

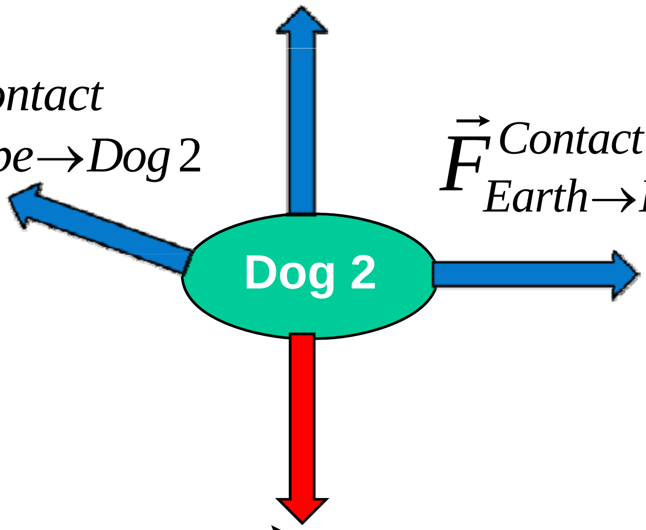
Provides information about:

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

$$\vec{F}^{\,Contact,Normal}_{Earth\rightarrow Dog\,2}$$

$$\vec{F}^{\,Contact}_{Rope\rightarrow Dog\,2}$$

$$\vec{F}^{\,Contact,Friction}_{Earth\rightarrow Dog\,2}$$



$$\vec{F}^{\,Gravity}_{Earth\rightarrow Dog\,2}$$

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.

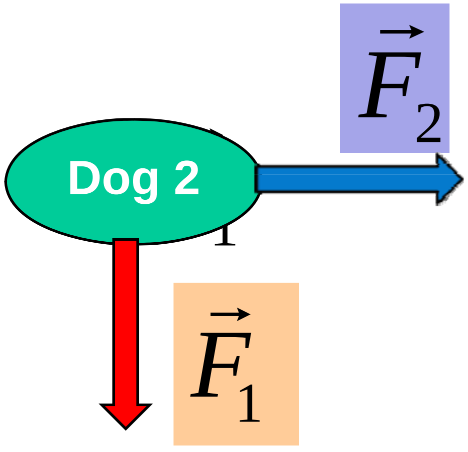
$$\hat{i},\ \hat{j}$$

- A force vector is written

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

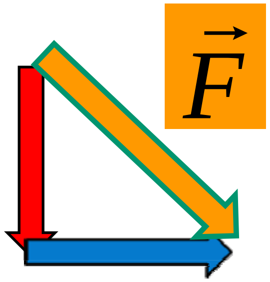
Adding Forces

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



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

Adding Vectors Head to Tail



Draw Vector for $\vec{F} = \vec{F}_1 - \vec{F}_2$

(Whiteboard, TA & LA)

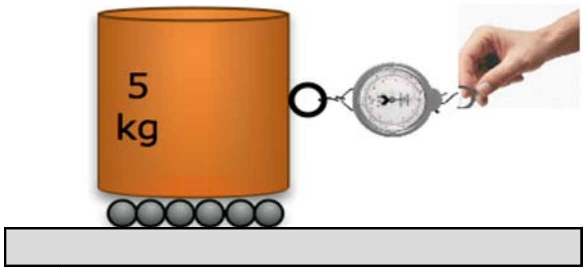
1. Same direction
2. Same magnitude
3. Same direction and magnitude
4. Same magnitude, opposite direction
5. Same magnitude, perpendicular direction
6. Neither same magnitude nor same direction

Compare the vector sums $\vec{C} = \vec{A} + \vec{B}$ and $\vec{D} = \vec{A} - \vec{B}$. In general, $\vec{C}$ and $\vec{D}$ have the

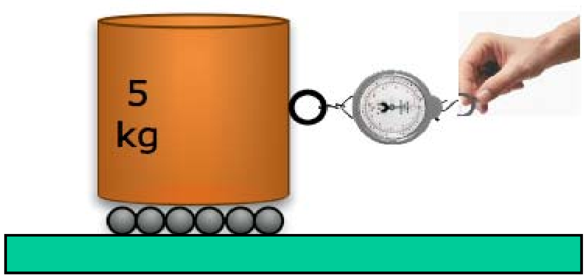
(Whiteboard, TA & LA)

1. Same direction
2. Same magnitude
3. Same direction and magnitude
4. Same magnitude, opposite direction
5. Same magnitude, perpendicular direction
6. Neither same magnitude nor same direction

System Schema

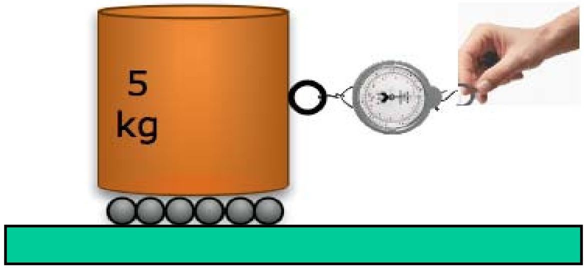


You are pulling the block along a table
To ensure that the block speeds up at a constant rate you need to



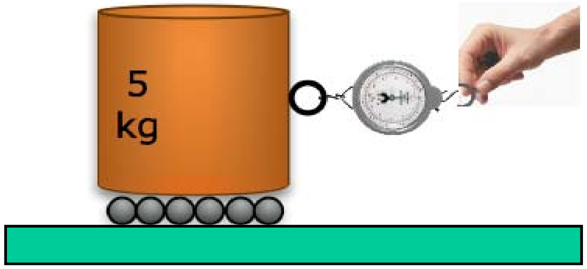
1. Pull with a decreasing force.
2. Pull with a constant force.
3. Pull with an increasing force.
4. Not pull at all.

You are pulling the block along a table.
To move the block at constant speed



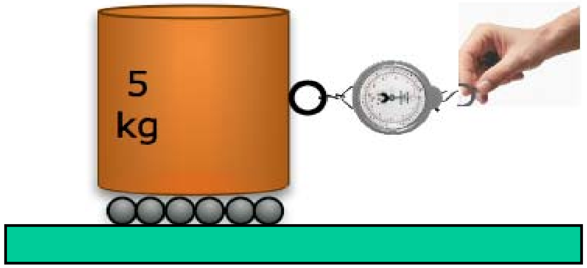
1. Pull with a decreasing force.
2. Pull with a constant force.
3. Pull with an increasing force.
4. Not pull at all.

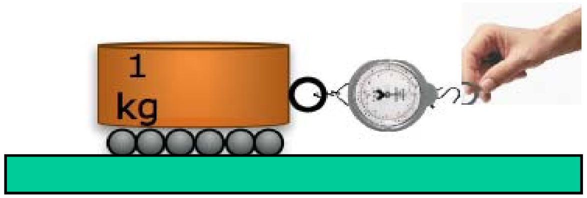
You are pulling the block along a table To move the block at constant speed



1. Pull with a decreasing force.
2. Pull with a constant force.
3. Pull with an increasing force.
4. Not pull at all.

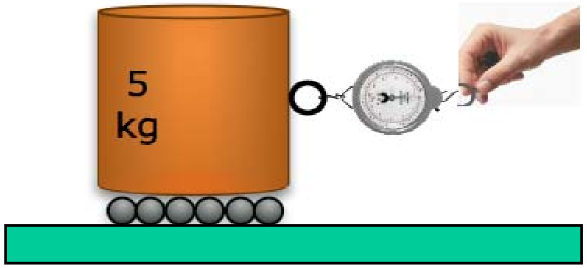
You are pulling two blocks along a table with constant speed (ignore friction). Which one requires a larger force?

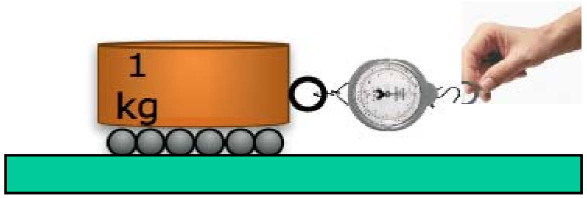




1. The 1 kg weight block
2. The 5 kg weight block
3. The require the same force.
4. There is not enough information to tell.

You are pulling two blocks along a table with equal acceleration. Which one requires a larger force?





1. The 1 kg weight block
2. The 5 kg weight block
3. The require the same force.
4. There is not enough information to tell.

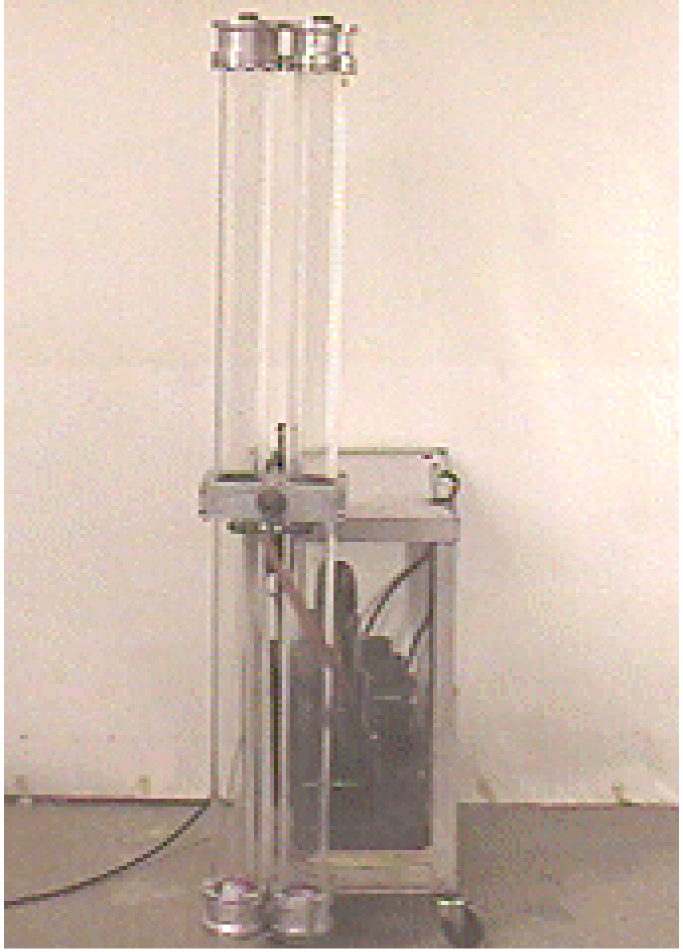
The prof drops two metal spheres, one of 1 kg, the other of 5 kg. Which object hits the ground first

1. 1 kg ball
2. 5 kg ball
3. Hit at the same time

The prof drops two metal spheres, one of 1 kg, the other of 5 kg. They hit the ground at the same time. The weight force on the 5 kg weight is:

A. Greater than the force on the 1 kg weight
B. Less than the force on the 1 kg weight
C. The same as the force on the 1 kg weight.
D. There is not enough information to tell.

Is it really true for ALL objects? Even a feather?



Weight Force W

- Experiment: See how it behaves
  when gravity is the <u>only</u> force acting on it.
  We expect it to speed up (accelerate).
  How does that acceleration depend on the object?

$$\vec{a}_A = \frac{\vec{W}_{E\to A}}{m_A}$$

The Gravitational Field Strength

- We find that, <u>when we can ignore the effects of air as another object that exerts force</u>, that all objects accelerate the same in free fall (only *W* acting).

$$\vec{a}_A = \vec{g} = \frac{\vec{W}_{Earth \to object}}{m_{object}} \qquad \vec{W}_{Earth \to object} = m_{object}\,\vec{g}$$

- Pseudo-independent of the object!
  (Do the experiment yourself!)
- constant "*g*" *gravitational field strength*. (Units of N/kg)

$$\vec{g} \approx 9.8 \text{ N/kg} \xrightarrow[down]{}$$

Foothold Ideas: Gravity

- Every object (near the surface of the earth) feels a downward pull proportional to its mass:

$$\vec{W}_{E\rightarrow m} = m\vec{g}$$

where $\vec{g}$ is referred to as *the gravitational field.*

- This is a force even though nothing touching the object is responsible for it.
- The gravitational field has the same magnitude for all objects irrespective of their motion and at all points.
- The gravitational field always points down.
- It is measured to be $g \approx 9.8\ \text{N/kg}$

Response to Gravity: Free Fall

- After an object has been released,
  - if it is dense enough so the forces from the air can be ignored
  - if nothing else is touching it

the only force acting on it is gravity.

$$\vec{a} = \vec{F}^{net}/m = \vec{W}_{E\to m}/m = m\vec{g}/m = \vec{g}$$

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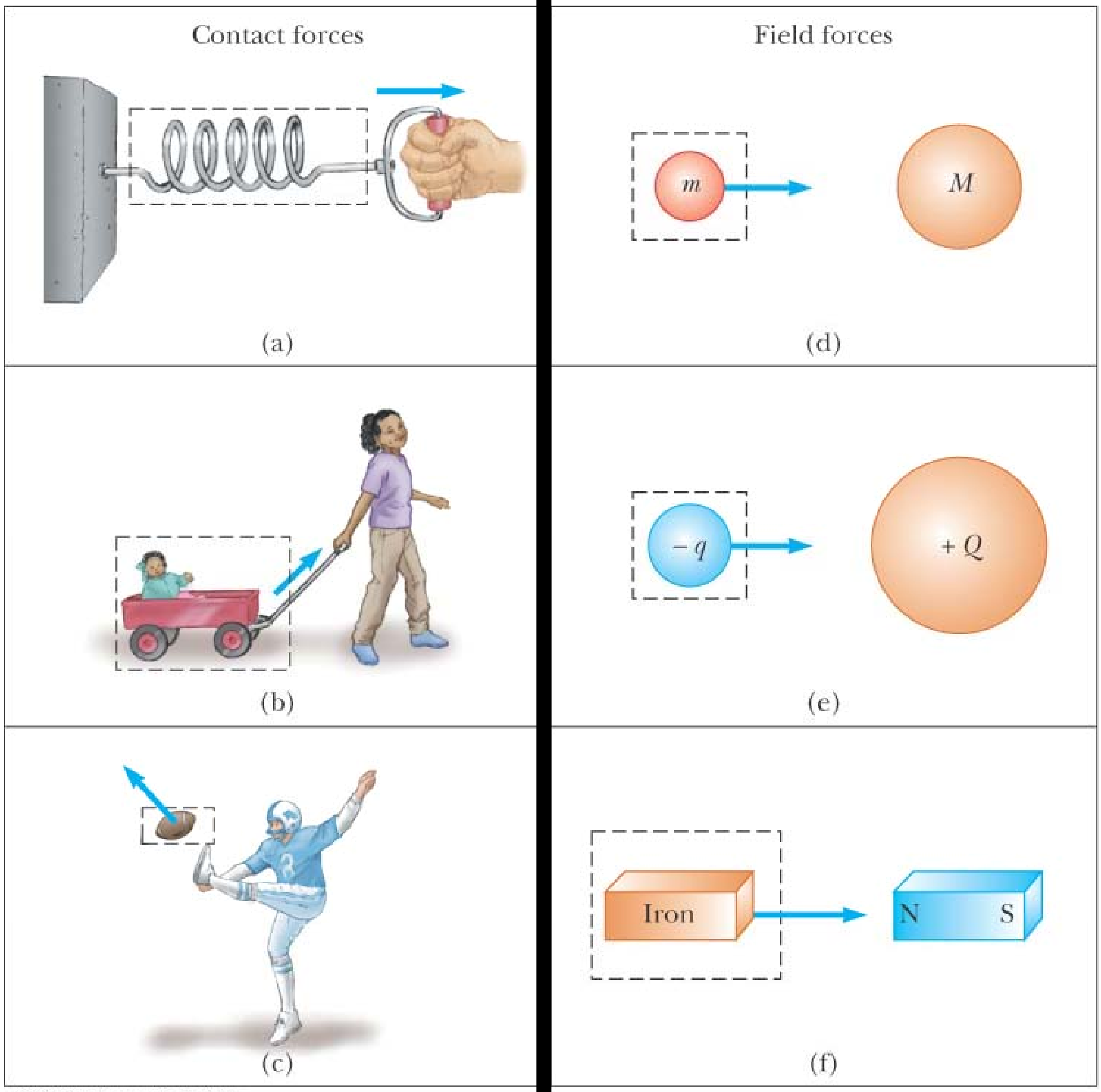
$$\vec{a} = \vec{F}^{net} \big/ m$$

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

Contact forces - due to physical contact with another object

Field forces – due to interaction FIELD which can act through empty space over long distance



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Gravity

Electrical

Magnetic

Kinds of Forces

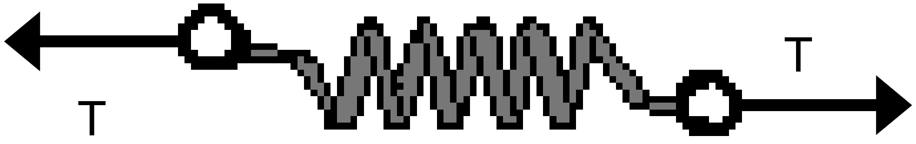
- Forces are what objects do to each other when they interact.
- Types of Force
  - – Normal: N
  - – Tension: T
  - – Friction: f, F^D, F^V
  - – Weight: W
  - – Electric: F^E
  - – Magnetic: F^M
- Notation convention.

$$\vec{F}^{\text{type of force}}_{\text{(object causing force)}\rightarrow\text{(object feeling force)}}$$

Tension:
The Spring

- Recall what we have learned about a spring.
- A spring changes its length in response to pulls (or pushes) from opposite directions.

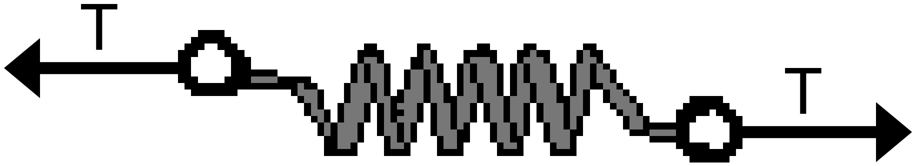
$$T = k\,\Delta l$$



Springs

- If you pull on a spring from both sides it changes its length.

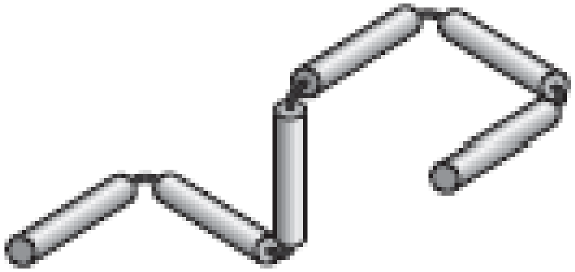
(“ΔL” = stretch or squeeze)



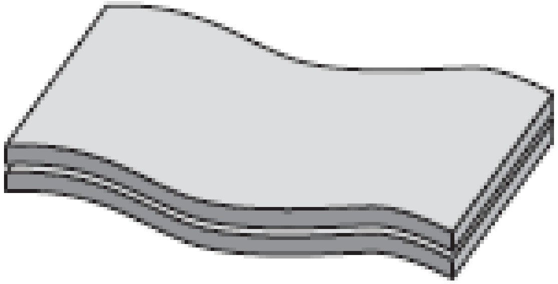
$$T = k\Delta L$$

- Holds for ALL objects interacting pulled by a spring!

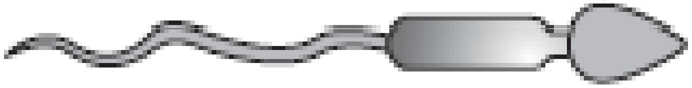
Springs in biology



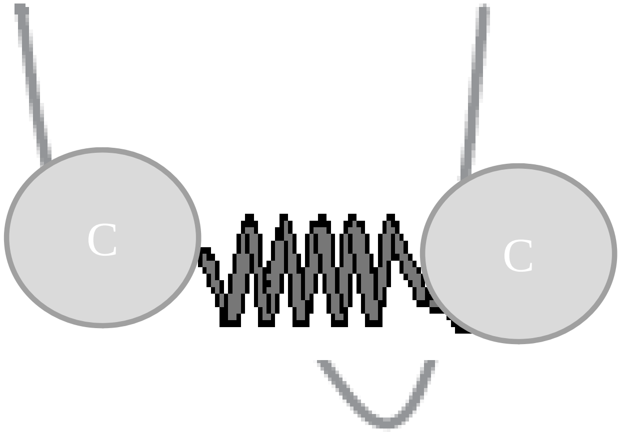
DNA polymer wriggling in solution



cell membrane fluctuating



flagellum beating on a swimming sperm



- Connected Atoms in molecules

From: Physical Biology of the Cell, Philips, Kondev, Theriot (2009)

Spring: The resistive force increases with deformation

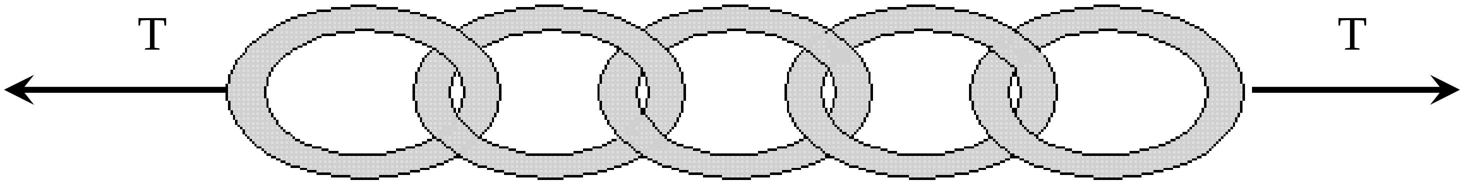
Show examples of materials or processes that could be modeled as springs in biology

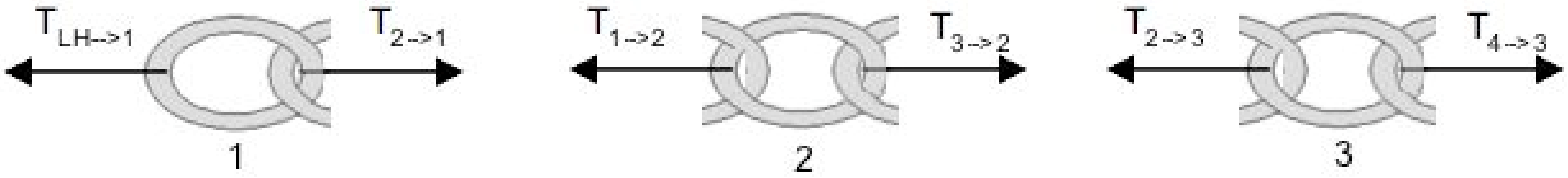
What are the benefits of Spring-like behavior?

(Whiteboard, TA & LA)

The Chain

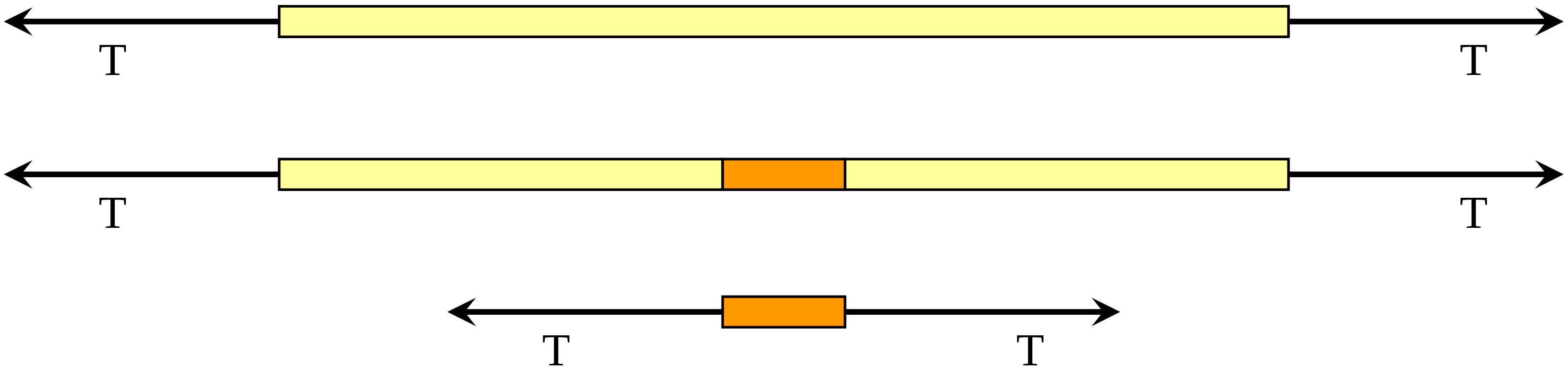
- Consider a series of links of chain being pulled from opposite directions.
  What are the forces on each link?





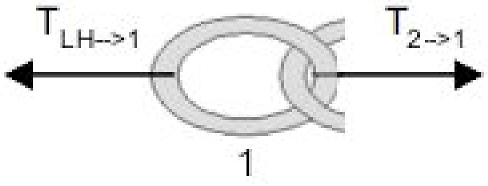
Tension:
The String

- A string is like a thin chain, but without easily identifiable links.
- We can imagine the string in parts and consider how each part acts on the others.

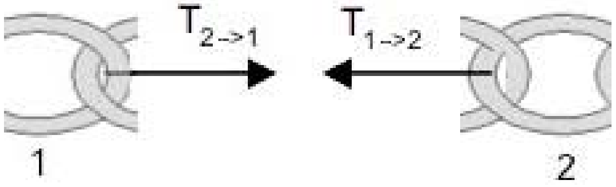


Which of the force pairs are examples of Newton’s third law

A



B



1. A
2. B
3. A and B
4. neither