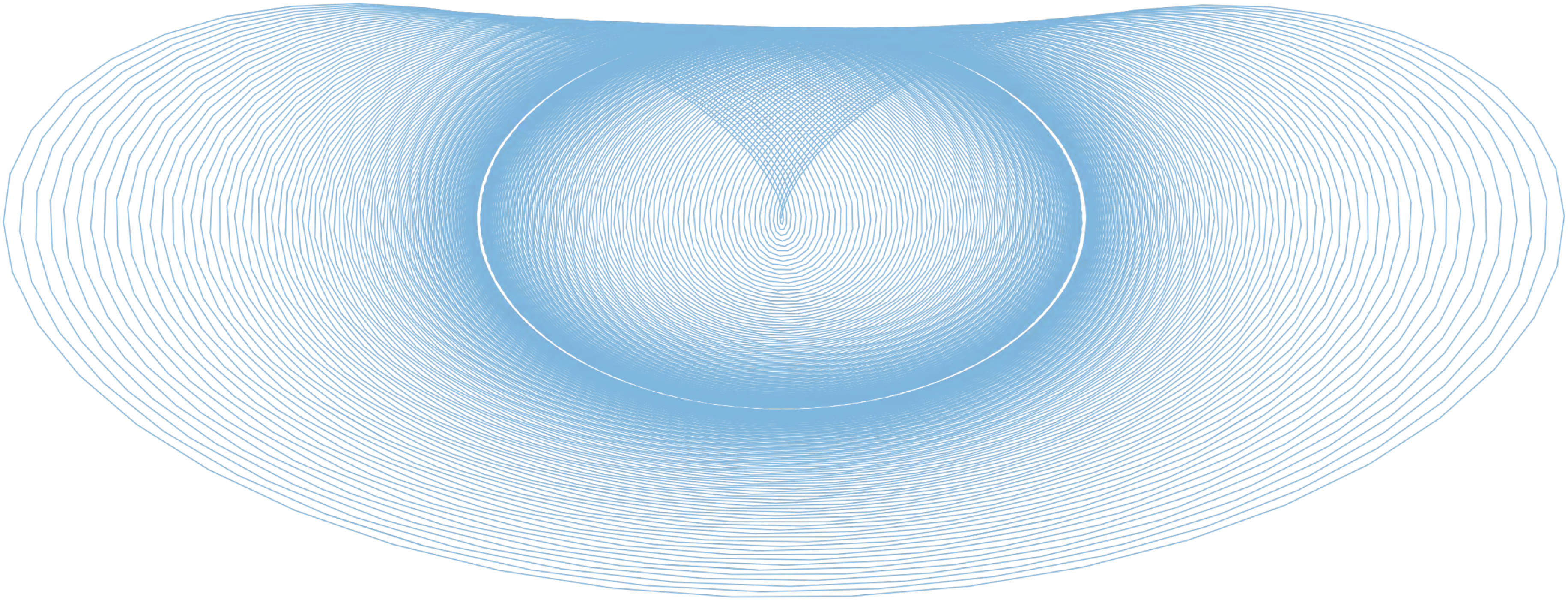
# PHYS 1420 (F19)
# Physics with Applications to Life Sciences

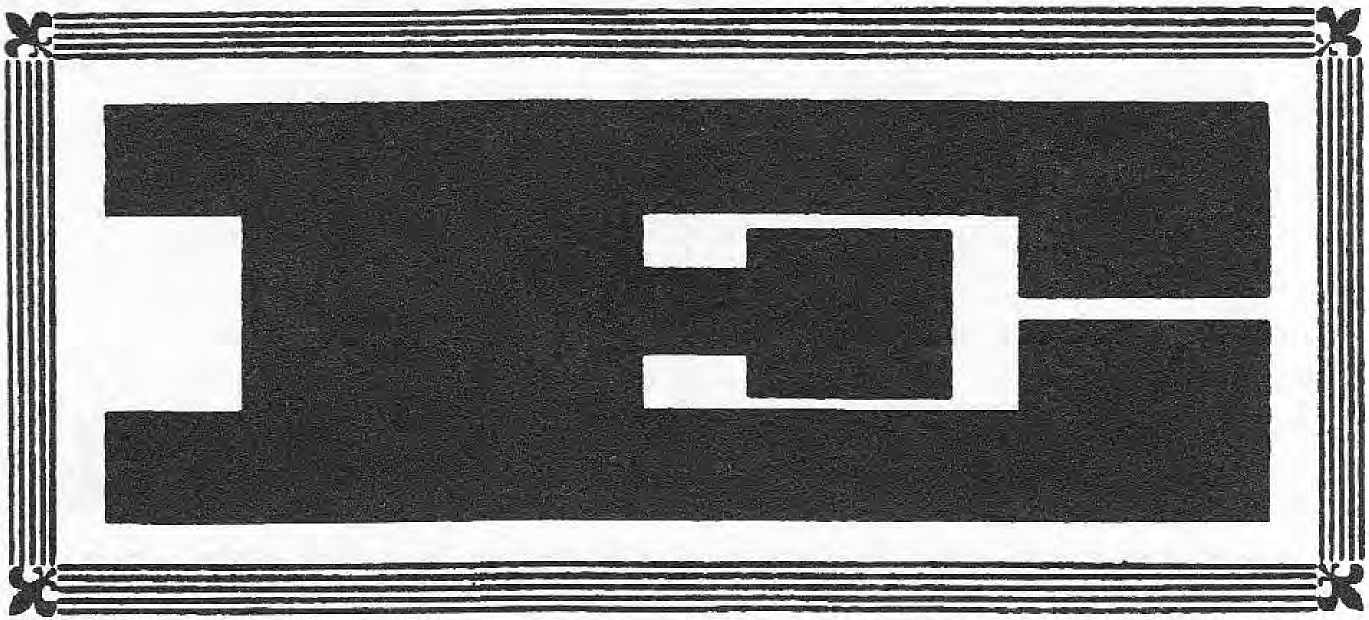


**2019.09.20**

Relevant reading:
Kesten & Tauck ch.4.1-4.3

Christopher Bergevin
York University, Dept. of Physics & Astronomy
Office: Petrie 240    Lab: Farq 103
cberge@yorku.ca

Ref. (re images):
Wolfson (2007), Knight (2017)



What do you think this is?

# Announcements & Key Concepts (re Today)

→ Online HW #3 posted and due Monday (9/23)

→ Written HW #1 posted and due 9/25 (in class at start of lecture)

Some relevant underlying concepts of the day…

- Equilibrium
- Forces
- Introduction to Newton's Laws
- "Fundamental" forces

# 4 Newton's Laws of Motion

- There are a **LOT** of deep/important concepts introduced in this chapter


# Force and Motion

- Consider this bit from another 1st year textbook
- The most fundamental comes right off the bat (pun!): *change*

## 4.1 The Wrong Question

### The Right Question

Our first question—about why the spacecraft keeps moving—is the wrong question. So what's the right question? It's the second one, about why the baseball's motion *changed*. Dynamics isn't about what causes motion itself; it's about what causes *changes* in motion.

# Uniform vs Changing Motion

- Subtle but important differences at play here....

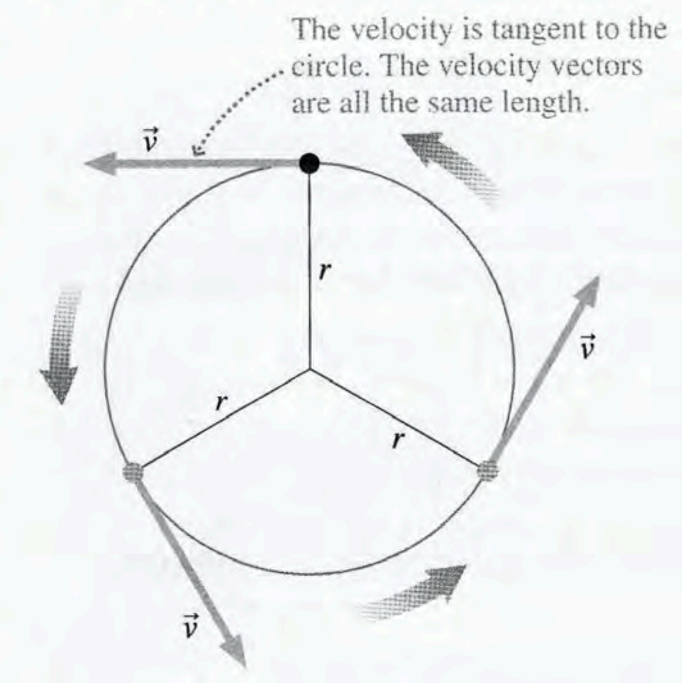
- Note that here some things are changing (e.g., θ, direction of $a$ and $v$)....

- ... while others are not (e.g., speed, magnitude of $a$ and $v$)

→ So in some sense, there is *changing change* (i.e., "non-uniform" motion) and *unchanging change* (i.e., "uniform" motion)

→ Such is the basis for introducing a key concept: *Force*

FIGURE 4.25 A particle in uniform circular motion.

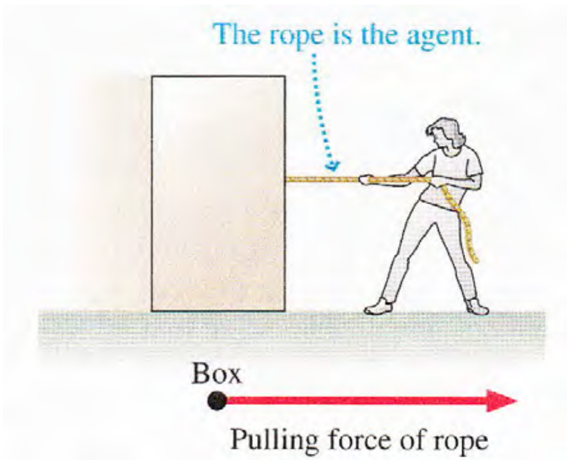



Note: You will see this distinction again elsewhere, though typically w/ different jargon (e.g., the notion of *steady-state* and *non-equilibrium* in chemistry/physics/biology)

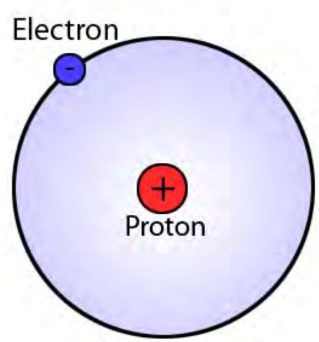
Careful: "Uniform motion" and "uniform circular motion" are not strictly the same thing....

# Force

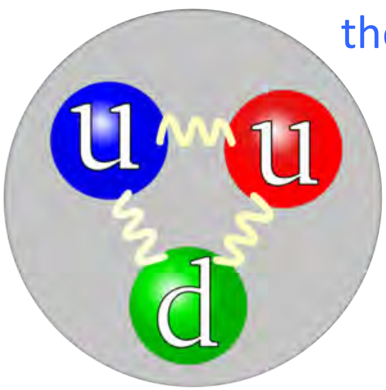
➢ Very fundamental concept in physics. Allows us to describe/understand how the motion of an object changes




Definition:
"Force causes change in motion"




the mundane




the sub-sub-atomic

the (sub-)atomic

the Felidaes

→ Consideration of forces is key to understanding all of it!

https://sciencebasedlife.wordpress.com/2012/04/13/how-do-cats-survive-falls-from-great-heights/

# Force

Solar/galactic dynamics

→ Consideration of forces is key to understanding all of it!

# <u>Force</u> (Interdisplinary point of view)

Membrane transport

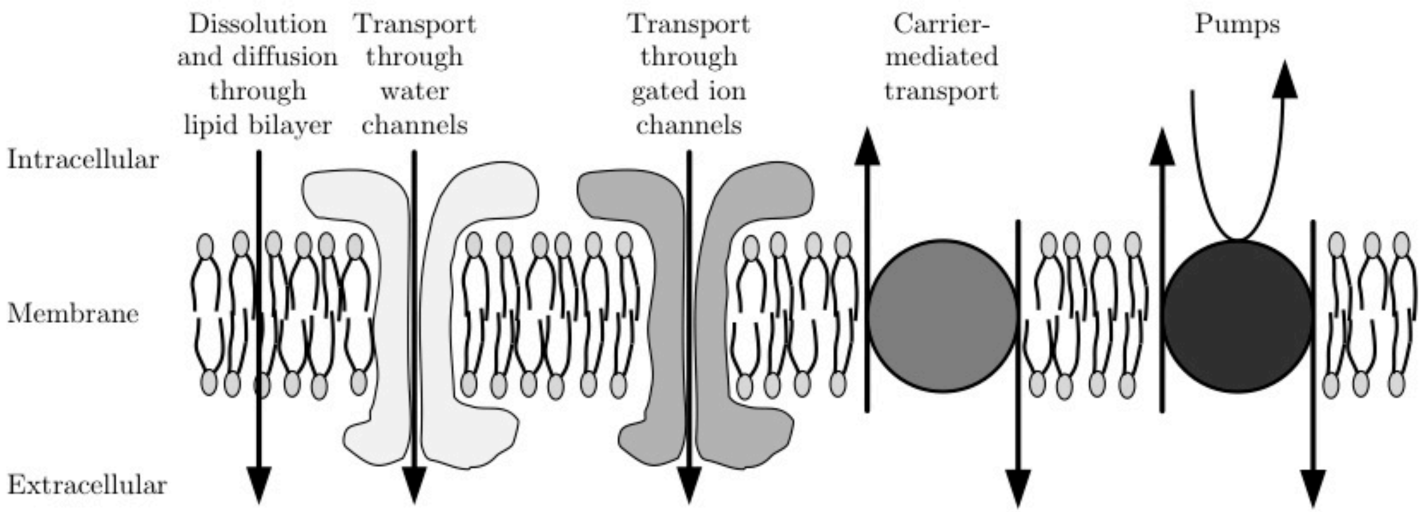
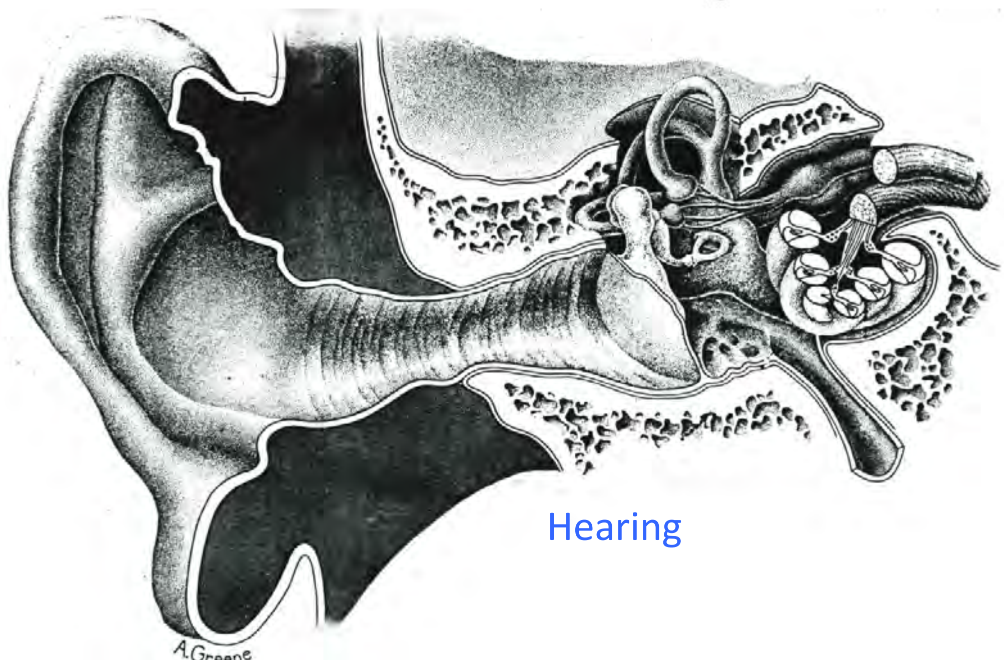
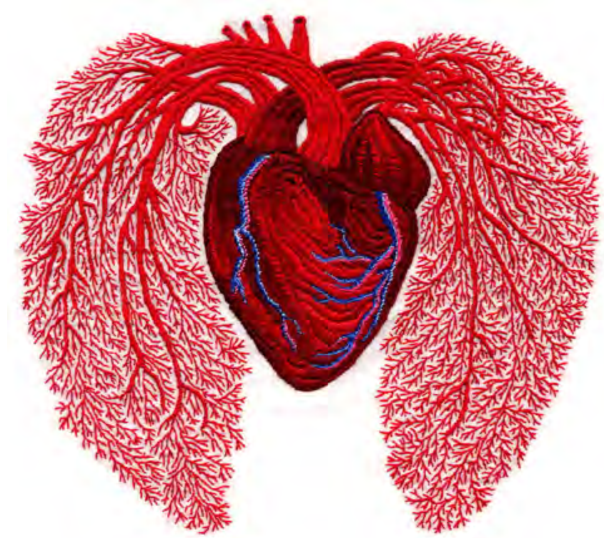



Figure 2.19

Cardiac/pulmonary dynamics




Hearing

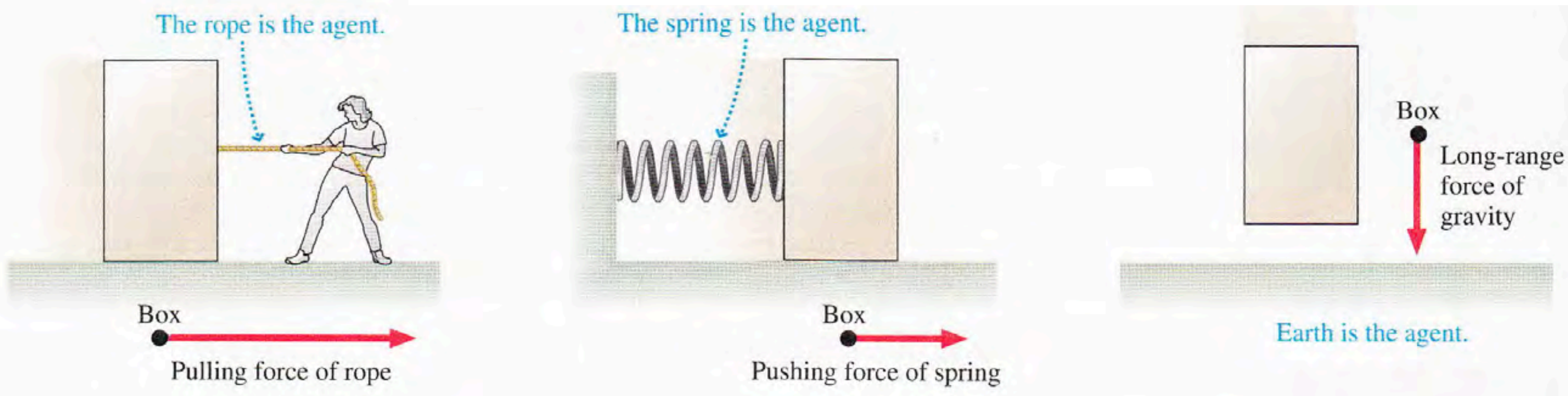


https://vivataurelia.wordpress.com/2012/02/14/the-human-heart/

→ Consideration of forces is key to understanding all of it!

# Force

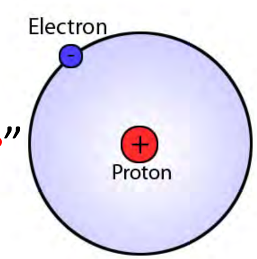
FIGURE 5.1 Three examples of forces and their vector representations.




- Vectors are very useful for dealing w/ forces

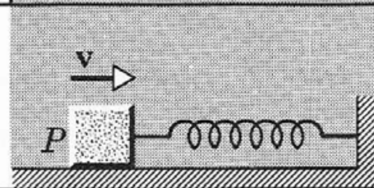
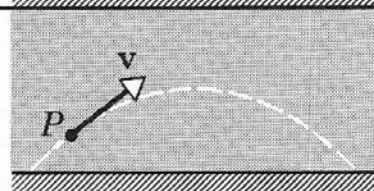
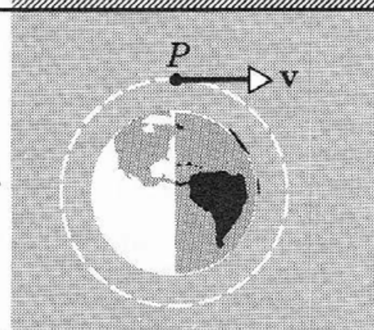
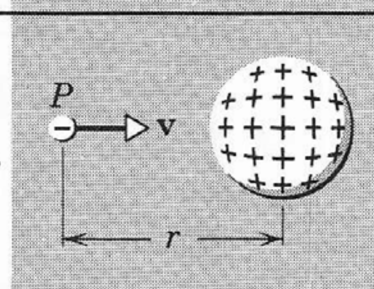
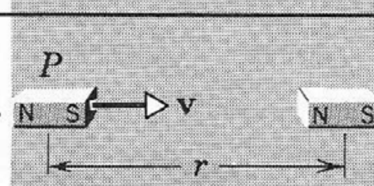
- Forces occur between things. Sometimes the two are readily apparent (e.g., the rope & the box) while other times it's more vague (e.g., Earth acting as a mysterious "agent")

- Such gets to a deeper mystery of "*action-at-a-distance*"
  (a topic at the foundation of much of physics!)



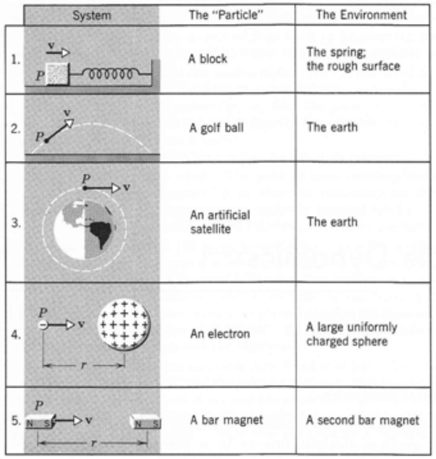

Knight (2013)

# <u>Forces</u> (Looking ahead...)

| | System | The "Particle" | The Environment |
|---|---|---|---|
| 1. |  | A block | The spring; the rough surface |
| 2. |  | A golf ball | The earth |
| 3. |  | An artificial satellite | The earth |
| 4. |  | An electron | A large uniformly charged sphere |
| 5. |  | A bar magnet | A second bar magnet |

Resnick & Halliday (1966)

# <u>Forces</u> (Looking ahead...)



| | System | The "Particle" | The Environment |
|---|---|---|---|
| 1. | | A block | The spring; the rough surface |
| 2. | | A golf ball | The earth |
| 3. | | An artificial satellite | The earth |
| 4. | | An electron | A large uniformly charged sphere |
| 5. | | A bar magnet | A second bar magnet |

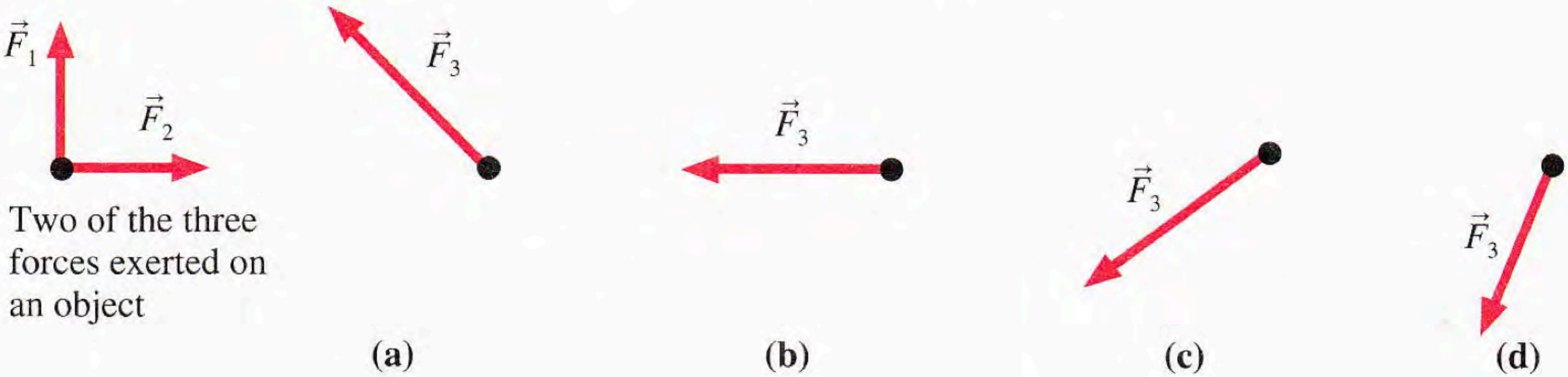
THE FORCE LAWS FOR THE SYSTEMS OF TABLE 5–1

| System | Force Law |
|---|---|
| 1. A block propelled by a stretched spring over a rough horizontal surface | (*a*) Spring force: $F = -kx$, where $x$ is the extension of the spring and $k$ is a constant that describes the spring; **F** points to the right; see Chapter 15<br>(*b*) Friction force: $F = \mu mg$, where $\mu$ is the *coefficient of friction* and $mg$ is the weight of the block; **F** points to the left; see Chapter 6 |
| 2. A golf ball in flight | $F = mg$; **F** points down (see Section 5–8) |
| 3. An artificial satellite | $F = GmM/r^2$, where $G$ is the *gravitational constant*, $M$ the mass of the earth, and $r$ the orbit radius; **F** points toward the center of the earth; see Chapter 16. This is *Newton's law of universal gravitation* |
| 4. An electron near a charged sphere | $F = (1/4\pi\epsilon_0)eQ/r^2$, where $\epsilon_0$ is a constant, $e$ is the electron charge, $Q$ is the charge on the sphere, and $r$ is the distance from the electron to the center of the sphere; **F** points to the right; see Chapter 26. This is *Coulomb's law of electrostatics* |
| 5. Two bar magnets | $F = (3\mu_0/2\pi)\mu^2/r^4$, where $\mu_0$ is a constant, $\mu$ is the *magnetic dipole* moment of each magnet, and $r$ is the center-to-center separation of the magnets; we assume that $r \gg l$, where $l$ is the length of each magnet; **F** points to the right |

Resnick & Halliday (1966)

Ex.

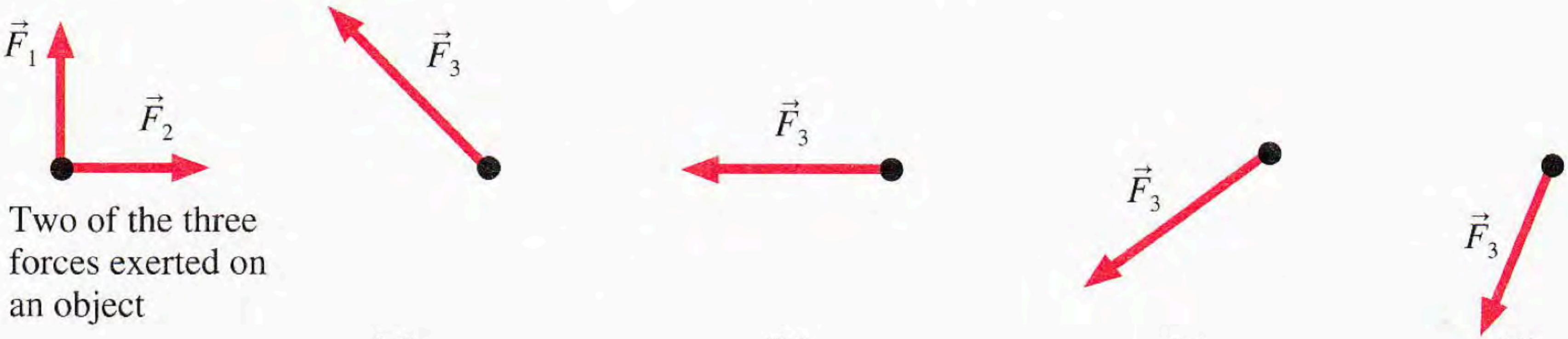
**STOP TO THINK 5.1** Two of the three forces exerted on an object are shown. The net force points to the left. Which is the missing third force?




Knight (2013)

Ex. (SOL)

**STOP TO THINK 5.1** Two of the three forces exerted on an object are shown. The net force points to the left. Which is the missing third force?




Two of the three forces exerted on an object

(a) (b) (c) (d)

c

Ex.

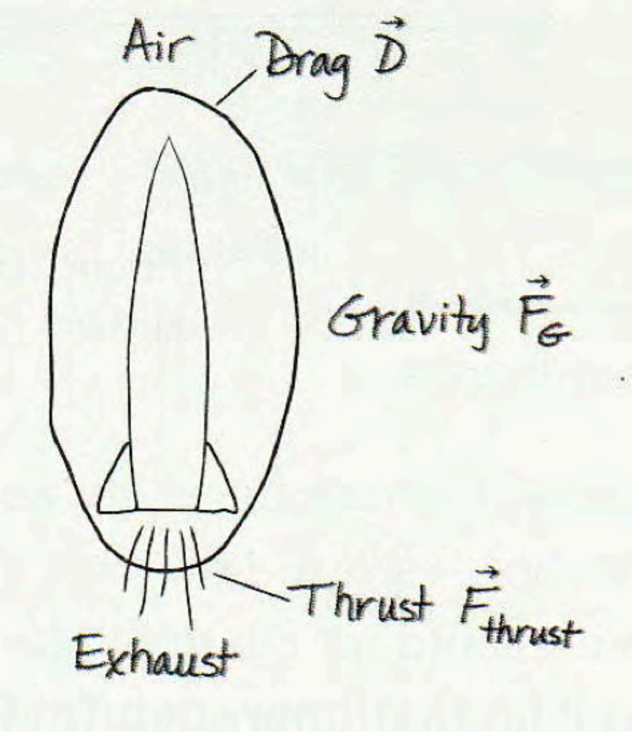
A rocket is being launched to place a new satellite in orbit. Air resistance is not negligible. What forces are being exerted on the rocket?

Knight (2013)

Ex. (SOL)

A rocket is being launched to place a new satellite in orbit. Air resistance is not negligible. What forces are being exerted on the rocket?

→ For a "real" rocket, there are likely more forces than these (e.g., stabilizer thrusters)




Knight (2013)

SCIENCE \ SPACE \ SPACEX

# Watch SpaceX's Falcon 9 rocket land, tip over, and explode

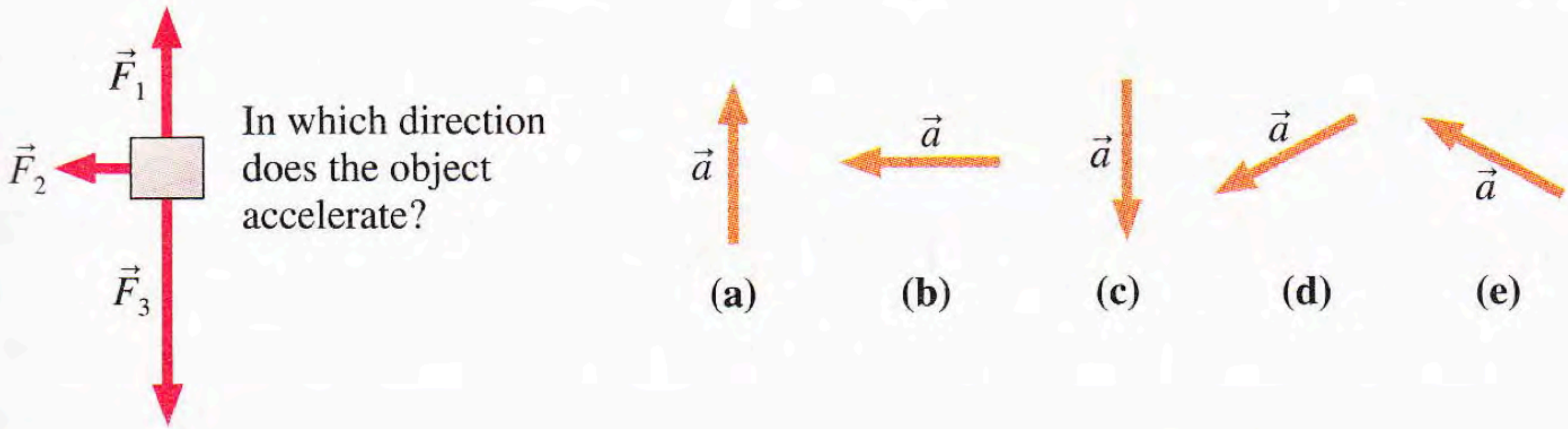
By Sam Byford | @345triangle | Jan 17, 2016, 10:24pm EST

https://www.theverge.com/2016/1/17/10784408/spacex-rocket-landing-explosion-falcon-9

https://www.youtube.com/watch?v=bvim4rsNHkQ

Ex.

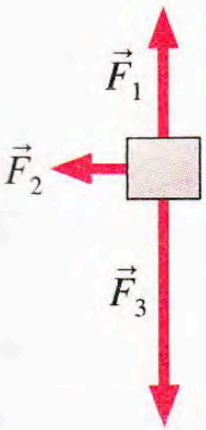
**STOP TO THINK 5.4** Three forces act on an object. In which direction does the object accelerate?



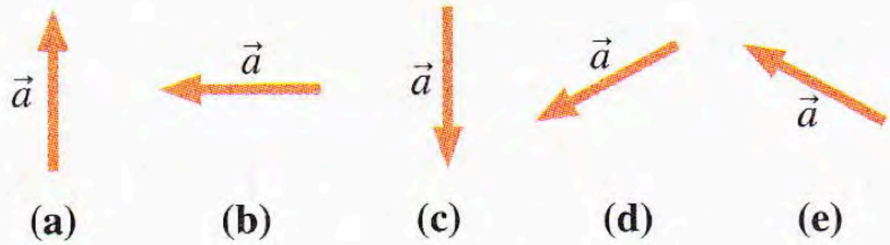

Knight (2013)

Ex. (SOL)

**STOP TO THINK 5.4** Three forces act on an object. In which direction does the object accelerate?




In which direction does the object accelerate?

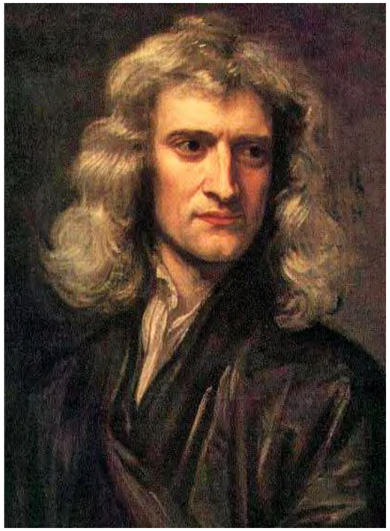



d

Knight (2013)

# Newton's Laws

I. Newton (1643 -1727)



- Three (seemingly innocuous) rules for motion/forces

**Newton's first law of motion:** A body in uniform motion remains in uniform motion, and a body at rest remains at rest, unless acted on by a nonzero net force.

**Newton's second law of motion:** The rate at which a body's momentum changes is equal to the net force acting on the body:

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt} \qquad \text{(Newton's 2}^{\text{nd}}\text{ law)} \qquad (4.2)$$

$$\vec{F}_{\text{net}} = m\vec{a} \qquad \text{(Newton's 2}^{\text{nd}}\text{ law, constant mass)}$$

→ We will be using this one (a LOT)

**Newton's third law of motion:** If object A exerts a force on object B, then object B exerts an oppositely directed force of equal magnitude on A.

- Wrapped up here are other key notions such as *inertia* and *momentum*
  (we'll be revisiting these plenty)

Wolfson

<u>Aside</u>: Fundamental Forces

- Four (er, three?) fundamental forces that govern, well, everything

    1. Gravity
    2. Electromagnetic
    3. Weak nuclear (deals w/ radioactive decay, e.g., $\beta$–decay)
    4. Strong nuclear (deals w/ what holds sub-atomic particles together)

- Our daily life perceptions are dominated by the first two:

    → PHYS 1420 will focus solely on those two

<u>Aside</u>: Trying to "unite" these = major goal in physics (e.g., "Standard model", string theory)

Ex.

If I drop a bowling ball, a spoon, and a book at the same time from the same height, do they fall at the same rate?

If you ask people around you, what will they say? I bet the will say one of the following answers:

- Heaver objects fall faster. If you drop a heavy and light object together, the heavy one will get to the ground first.
- This is trick question. I remember in physics that everything falls the same. You can't trick me twice.

https://www.wired.com/2013/10/do-heavier-objects-really-fall-faster/