ALGEBRA-BASED PHYSICS-2: ELECTRICITY, MAGNETISM, AND MODERN PHYSICS (PHYS135B-01): UNIT 0

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1. Professor Jordan Hanson
2. Contact: jhanson2@whittier.edu, SLC 212
3. Syllabus: Moodle (will examine shortly)
4. Office hours: Tuesdays 12:00-17:00
5. PHYS135A
6. Text: College Physics (openstax.org), see link on syllabus.
7. Homework: Online (ExpertTA, $32.50)

SUMMARY

Physics - $\phi\upsilon\sigma\iota\kappa\acute{\eta}$ - ”phusiké”: *knowledge of nature*
from $\phi\acute{\upsilon}\sigma\iota\varsigma$ - ”phúsis”: *nature*
Reading: Chapters 18 and 19 (for Unit 1)

1. Estimation/Approximation
2. Review of concepts from Newtonian mechanics
    - Kinematics and Newton’s Laws
    - Work-energy theorem, energy conservation
    - Momentum, conservation of momentum

Bonus Essay assignment: Students may submit an essay on the history of scientific developments covered in the course, due at the end of the semester. The essay must be 10 pages, address scientific arguments and results, and must include references. The grade of this paper will replace the lowest midterm grade, if it would raise the final grade. Example topics:

- Measurement of cosmic ray flux by Victor Hess
- Discovery of the charge to mass ratio of the electron by J.J. Thompson
- First description of the *photoelectric effect* by Albert Einstein

(Before beginning the essay, please discuss it with me in office hours).

Estimation/Approximation

In science and engineering, estimation is to obtain a quantity in the absence of precision, informed by rational constraints.

1. Define relevant unit scales: (mg, g, or kg), (m/s or km/hr)
2. Obtain complex quantities from simple ones
    - Obtain *areas* and *volumes* from *lengths*
    - Obtain *rates* from *numerators* and *denominators*
3. **Scaling problems: how does a complex quantity depend on other quantities?**
4. Constrain the unknown with upper and lower limits

(Professor: work an example of each on the board).

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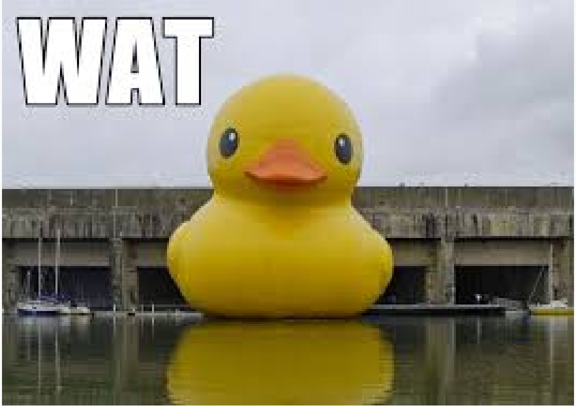

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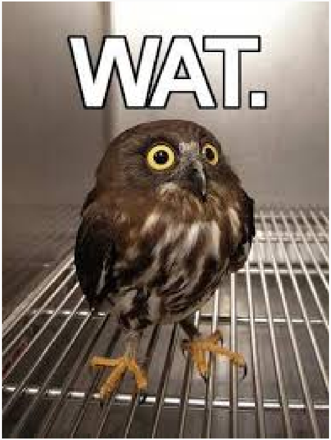

Unit scale: The distance between the Earth and the sun is 1 AU. What is the distance between the Sun and Venus?

- A: 10 million km
- B: 100 million km
- C: 0.2 AU
- D: 0.7 AU

Unit scale: The distance around a track is 400 m. Which of the following is the time it takes a fast runner to proceed all the way around the track?

- A: 4 seconds
- B: 0.1 minutes
- C: 1.0 minute
- D: 20 minutes

Volumes from other quantities: A jar at the coffee shop is filled with coffee beans, and we can win a prize for guessing the number of beans. If the radius of the jar is about 4 cm, and the height is about 10 cm, how many beans are in the jar?

- A: 200
- B: 2,000
- C: 10,000
- D: Um, like, a million...

Rates from other quantities: A student travels from uptown Whittier to SLC in roughly 10 minutes. What is her average speed?

- A: 0.1 m/s
- B: 0.33 m/s
- C: 1.33 m/s
- D: 10 m/s

Scaling problem: If the *temperature* of a gas remains constant, the *pressure* is inversely proportional to the volume of the gas. If the volume of a cylinder is *decreased* by a factor of three, by what factor does the pressure change, if the temperature remains the same?

- A: 3
- B: 1/3
- C: 1
- D: 9

Scaling problem: The gravitational pull between two massive objects is inversely proportional to the *distance squared* between them. By what factor does the force of gravity between two objects change if the distance between them is *decreased* by a factor of 2.0?

- A: 2.0
- B: 0.5
- C: 4.0
- D: 0.25

Constrain the unknown with lower and upper limits: How many books are there in Wardman Library?

This is a group board problem. Complete this estimation with your group.

(Professor: white board space...)

$\vec{p} = 4\hat{i} + 2\hat{j}$. $\vec{q} = -4\hat{i} + 2\hat{j}$.
Compute $\vec{p} + \vec{q}$.

- A: $4\hat{i} + 4\hat{j}$
- B: $0\hat{i} + 4\hat{j}$
- C: $4\hat{i} + 0\hat{j}$
- D: 0

$\vec{p} = -1\hat{i} + 6\hat{j}$. $\vec{q} = 3\hat{i} + 0.5\hat{j}$.
Compute $\vec{p} \cdot \vec{q}$.

- A: -1
- B: 1
- C: 0
- D: 3

Kinematics and Newton's Laws

Kinematics - A description of the motion of particles and systems
Dynamics - An explanation of the motion of particles and systems

What causes an object to move? **Forces**. Forces exist as a result of the **interactions** of objects or systems.

Evolution - A description of the change of biological species
Natural Selection - An explanation of change in biological species

What causes species to evolve? **Natural selection**. Natural selection exists because of election pressures, numerous offspring, and variation among offspring.

Newton's First Law: A man slides a palette crate across a concrete floor of his shop. He exerts a force of 60.0 N, and the box has a constant velocity of 0.5 m/s. What force cancels his pushing force, and what is the value in Newtons?

- A: wind, 60.0 N
- B: friction: 60.0 N
- C: friction: -60.0 N
- D: weight: -60.0 N

Newton's Second Law: The crate has a mass of 50 kg, and encounters an area where there is no longer friction. If the pushing force is still 60 N, what is the acceleration?

- A: 1.0 m/s^2
- B: 0.8 m/s
- C: 1.2 m/s
- D: 1.2 $m/^2$

Kinematics: If the acceleration is 1.2 m/s^2, and the crate begins with a velocity of 1 m/s, what is the velocity after 5 seconds?

- A: 4 m/s
- B: 5 m/s
- C: 6 m/s
- D: 7 m/s

Newton's Second Law: Suppose there is no pushing force, but the crate moves at 5 m/s through an area with a frictional force that has a magnitude of 5 N. If the crate still weighs 50 kg, what is the acceleration?

- A: 0.2 m/s^2
- B: -0.1 m/s^2
- C: 1 m/s^2
- D: -2 m/s^2

Newton's Third Law: If a person hangs from a horizontal rope (with the ends tied to two walls), and the person has a weight $\vec{w} = -600N$, what is the total upward component of the tension in the rope?

- A: -600 N
- B: 60 N
- C: 600 N
- D: -60 N

Newton's Third Law: If a heavy truck and a light car collide, which exerts the larger force on the other?

- A: The heavy truck exerts a larger force on the car.
- B: The light car exerts a larger force on the heavy truck.
- C: They exert the same force on each other.
- D: Cannot determine.

WORK-ENERGY THEOREM AND CONSERVATION OF ENERGY

Group board exercise: A firework of mass 1 kg is launched straight upwards. The gunpowder releases 500 J of energy. What is the velocity of the shell as it leaves the launcher? How high does it fly straight upwards?

(Professor: review 1. Work equation 2. Work-energy theorem 3. gravitational potential energy).

Work-energy theorem: The force to compress a spring with a spring constant k by a displacement Δx is:

- A: $-k\Delta x^2$
- B: $k\Delta x^2$
- C: $-k\Delta x$
- D: $k\Delta x$

Work-energy theorem: How high in the air would a 0.1 kg rock go if it was launched straight upward by a spring with $k = 1000$ N/m, if the spring was compressed 0.1 m?

- A: 1 m
- B: 10 m
- C: 50 m
- D: 100 m

In the first semester we encountered *irreversable* processes: energy lost to *friction*, and energy lost to *drag*. The irreversable process is a deeper notion in thermal physics, because it leads to the Second Law of Thermodynamics (see 200-level physics courses).

Group board exercise: Suppose a system moves at constant speed along a rough surface. Draw two closed, two-dimensional paths, each describing the trajectory of the system. A closed path means the system has a final displacement of zero. Recall that the frictional force is not conservative. Which path requires more work?

Key question: If the speed is constant the entire time, and one path requires more work than the other, what happens to the excess energy (*they have the same final kinetic energy*)?

MOMENTUM

An object that has a small mass (m) and an object that has a large mass ($10m$) have the same momentum. Which mass has the largest kinetic energy?

- A: The one with the small mass
- B: The one with the large mass
- C: If the momentum is the same the kinetic energy is the same
- D: Cannot determine the answer

Two objects with equal mass have a total momentum of zero. Which of the follow is true of the velocities of the objects?

- A: They are equal, and in the same direction.
- B: They are equal, and in the opposite direction.
- C: They are equal, and perpendicular.
- D: They are unequal, but in the same direction.

A ball with mass 0.1 kg moves at 1 m/s. It strikes a stationary ball with twice the mass and stops. The heavier ball moves with a velocity of

- A: 0.1 m/s
- B: 1 m/s
- C: 5 m/s
- D: 0.5 m/s

The momentum of inertia of an object with mass m as it revolves around an origin at a distance r is $I = mr^2$, and the *angular momentum* is $L = I\omega$, where ω is the angular velocity. (Professor: do one example).

If the mass of an object that is rotating around an origin with angular velocity ω decreases by a factor of 2, the new angular velocity will be:

- A: $-\omega$
- B: -3ω
- C: 2ω
- D: ω

Real-world situation with angular momentum:
`https://www.youtube.com/watch?v=g-jlQaYKN9M`

CONCLUSION

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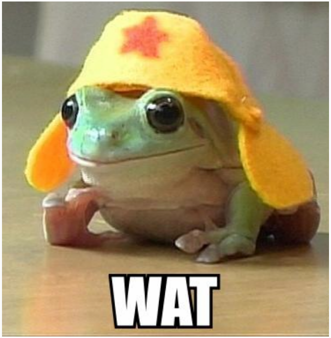

Reading: Chapters 1 and 2 (for Unit 1)

1. Estimation/Approximation
    - Estimating the correct order of magnitude
    - Building complex quantities
    - Unit analysis
2. Review of concepts from Newtonian mechanics
    - Kinematics and Newton's Laws
    - Work-energy theorem, energy conservation
    - Momentum, conservation of momentum

ANSWERS

ANSWERS

- 0.7 AU
- 1 minute
- 2000
- 0.33 m/s
- 3
- 4
- (White board problem): about 200,000
- $0\hat{i} + 4\hat{j}$
- 0
- friction: -60.0 N
- 1.2 m/s^2
- 7 m/s
- -0.1 m/s^2
- -600 N
- They exert the same force on each other.
- $-k\Delta x$
- 100 m
- The one with the small mass
- They are equal, and in the opposite direction.
- 0.5 m/s
- 2ω