Physics 121
Class 10

Today

• Today you will learn (or review) how to do a wide variety of force problems.
• You will learn about Newton’s Law of Universal Gravitation

Seeing Your Test Results

In a few days you will be able to see:
• The test
• Your answers
• The correct answers

Notes on Grades

• I do not give extra credit because extra credit either means
  • letter grades are higher than they should be
  • those who don’t do extra credit are hurt - which means it’s not really extra credit
• Your test results are the best indicator I have of your individual mastery of the material.
• Everyone has better days than others, and that usually averages out with 5+ tests
• Tests count a total of 50% of your total grade
Schedule

• HW #9 is due Friday, as usual.
• Lab #3 is up this week.
• Quiz #3 is due Monday rather than Saturday.

Last Time

• Projectile Motion
• Collisions in 2-Dimensions
• Velocity Addition and Relative Velocity in 2-D

Velocity Addition Problem

You have a large cattle ranch with a river running through it. The river is fairly calm, and flows to the west with a speed of 1.25 m/s. You’ve found from experience that the best way to cross the river directly to the north is to row toward a particular mountain in the distance. The mountain’s compass bearing is 23.0 degrees. If you rowed at the same speed in a lake, how fast would you be going?
The “Fundamental” Forces

1. Gravitation - mutual attraction between all matter, very weak, infinite range
2. Weak (Nuclear) - responsible for beta decay, weak, range is ~1/100 the size of a proton
3. Electromagnetic - responsible for most of the interactions in matter, strong, infinite range
4. Strong (Nuclear) - holds nuclei together, range is about the size of a proton

An Updated Version

1. Gravitation - mutual attraction between all matter, very weak, infinite range
2. Weak (Nuclear) - responsible for beta decay, weak, range is ~1/100 the size of a proton
3. Electromagnetic - responsible for most of the interactions in matter, strong, infinite range
4. Strong (Nuclear) - holds quarks together in a proton, the strong force is just the weak residual effects of the color force, infinite range with force increasing as separation distance grows

Forces at a Distance

Electrostatic (Don’t need to know)

\[ \vec{F}_e = k \frac{q_1 q_2}{r^2} \hat{r} \]

Gravitational (more later)

\[ \vec{F}_g = -G \frac{m_1 m_2}{r^2} \hat{r} \] or \[ \vec{F}_g = m\vec{g} \]
Contact Forces

- “Pushing and pulling”
- Tension in a rope
- Surface forces
  - Normal force
  - Friction
    - Static
    - Kinetic
    - Rolling
- Springs (later)
- Drag (air resistance, later)

Gravity

Force at a Distance

“Occult quality” “Self-perpetuating miracle”

Local Gravity

How do the gravitational forces on two objects compare?
Astronomical Gravity

Inverse Square

\[ F = \frac{GMm}{r^2} \quad \text{or} \quad \vec{F} = -\frac{GMm}{r^2} \hat{r} \]
\[ G = 6.674 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \]

Find the radius of the earth.

\[ F = \frac{GMm}{r^2} \]
\[ G = 6.674 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \]
\[ M = 5.972 \times 10^{24} \text{kg} \]

Astronomical Gravity

How much are you attracted to the person sitting next to you?

\[ F = \frac{GMm}{r^2} \]
\[ G = 6.674 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \]

Flat Surfaces and Friction
**Kinetic Friction**

Kinetic friction is the force that opposes the motion of objects sliding over each other. The amount of force that friction produces depends on two things:

- The type of surfaces
- The normal force pushing the sliding object into the surface.

\[ F_k = \mu_k N \]

\( \mu_k \) ("mu-k") is called the "coefficient of kinetic friction.

Kinetic friction does negative work.

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**Static Friction**

If we pull on the block with the string, but the frictional force keeps the block from moving, there is still a frictioonal force. This is called static friction and its equation is: \( F_s \leq \mu_s N \)

\( \mu_s \) ("mu-s") is called the "coefficient of static friction." The inequality means that the static friction will balance out the tension until the tension is large enough to start the block moving. Static friction does no work.

\( \mu_s > \mu_k \) Why??

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**Friction - Rolling**

When an object rolls, the surfaces don’t rub past each other (much). Ideally, frictional force doesn’t cause energy loss.

\[ \vec{F} \neq \mu \vec{N} \]

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**Friction - Rolling**

Can rolling friction cause an object to go faster?
Friction - Rolling

We'll study rolling later. We'll ignore effects of rotating wheels when we talk about cars.

Inclined Plane

This is perhaps the most important problem to know well!

Given $T$, $m$, $\theta$
Find $a$

Tension
Block and Tackle

The block and tackle has been used for centuries as a tool to be able to lift heavy objects.

It’s a little hard to visualize just what each rope does, so we’ll make an equivalent, but less practical system to analyze.


Block and Tackle

Draw free body diagrams for each pulley.

What is the tension in the rope?

What force is on each contact point with the ceiling?