Universal gravitation

Physics 211
Syracuse University, Physics 211 Spring 2023
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February 21, 2023

Announcements

Help hours in the few days: (more to be added next week)

- Today, 3:00-5:00 (probably – see next slide)
- Tomorrow, 2:00-4:00
- Thursday, 2:00-4:00
- Sunday, 2:00-5:00 PM, Stolkin Auditorium – a review for Exam 2

Exam 2 approaches

- Group Exam 2 is Thursday/Friday in recitation
- Exam 2 is next Tuesday
  - More details about Exam 2 on Thursday

Announcements

I'm sick with something. I don't know what, but it's not COVID (per antigen test).

I can't talk over a bunch of noise today in class. I will project as much as I can, but please be patient with me. :(

I may not be able to hold Clinic hours today. If I can't, I will be available on Discord / email from 3-5pm to help people with homework.

This also means I'm behind on some other stuff I need to do.

A block on a ramp

A block of mass m_1 rests on a ramp at angle θ; a weight of mass m_2 hangs over the side of the ramp. The coefficient of kinetic friction is μ_k.

Calculate its acceleration if it:

- ... slides down the ramp (m_2 is small)
- ... is pulled back up the ramp (m_2 is large)

An exam question from 2021: a Formula 1 car

Formula 1 cars are designed so that the air going over them creates extra aerodynamic forces on them that press them into the ground.

(This is called “down force”.)

Why is this useful?

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Let’s look at the 2021 exam question...

Homework questions?

A new force: Gravity, in general

- On Earth all objects experience a gravitational force proportional to their mass:
- $F_{\text{grav}} = mg$, directed down toward the Earth
  - How does this work when you're not on Earth?
  - What determines how big g is?

Newtonian gravity

- All objects – stars, planets, apples, people – exert forces on each other
- That force is given by

$$F_g = \frac{GMm}{r^2}$$

- M and m are the masses of the two objects (Sun and Earth, Earth and person, etc.)
- Both objects feel the same force, directed toward each other
- Note:

$$a_g = F_g/m = \frac{GM}{r^2}$$

- What is G?
- $\rightarrow$ Fundamental constant of nature that tells us how strong gravity is

What are the units of G?

(Remember, it appears in the equation $F_g = \frac{GMm}{r^2}$)

- a) $\mathrm{m/s^2}$
- b) $\mathrm{m^2/s^2}$
- c) $\mathrm{N \cdot m^2/kg^2}$
- d) $\mathrm{m^3 kg^{-1} s^{-2}}$

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$$G = 6.673 \times 10^{-11} \frac{\mathrm{N{\cdot}m^2}}{\mathrm{kg^2}}$$

  - This is really, really tiny

Measuring G

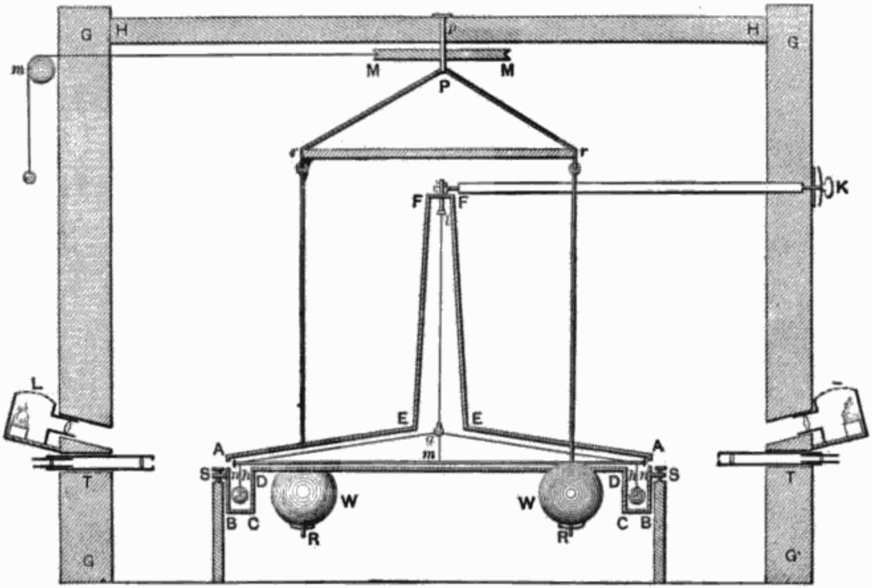


Fig. 1

Measuring G

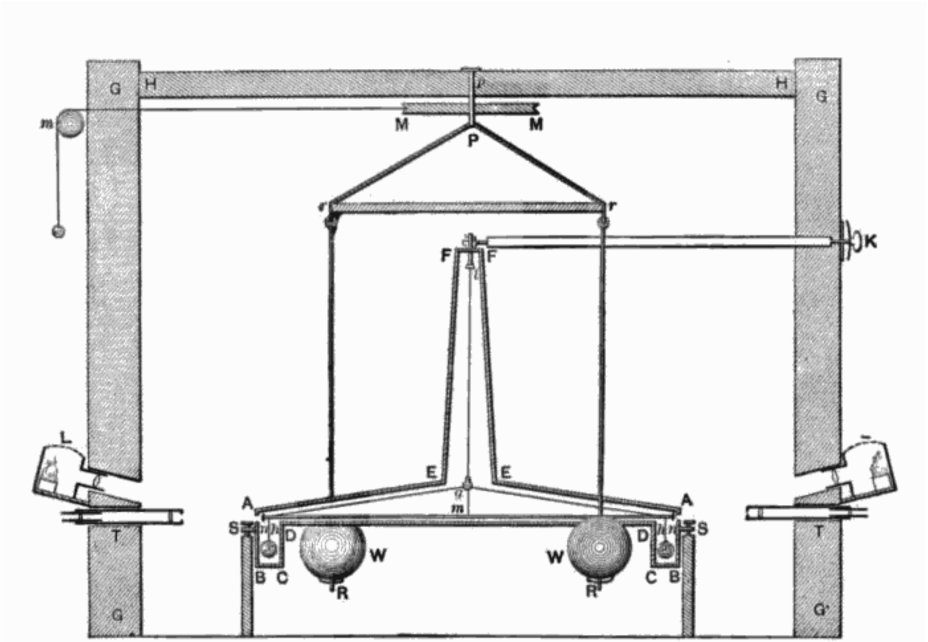
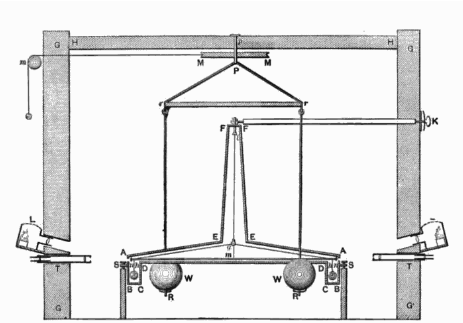


Fig. 1

What is the force between a 1kg mass and a 5kg mass that are 5cm apart?

Measuring G



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Back of the envelope math (in SI units):

$$F_g \approx \frac{(7\times 10^{-11})(5)(1)}{5\times 10^{-2}} = 7 \times 10^{-9}\ \text{N!}$$

Measuring the mass of the Earth

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We have two expressions for the gravitational force:

- $F_g = mg$, where g is an empirical measurement of Earth's gravity
- $F_g = GMm/r^2$, giving the force between any two objects (not just on Earth

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$M = \frac{gR^2}{G} = 5.97 \times 10^{24}$ kg...

Gravity and circular motion

- Many orbits are nearly circular
- Everything you learned last week about uniform circular motion still applies
- Weighing the Earth by looking at the Moon...
- These problems are nothing new and nothing hard; it's just a new force
- Problems involving orbits are often easier (fewer forces)

Weighing the Moon...