Physics 101 Lecture 17
Universal Gravitation

HW 7&8 due this Thurs.!

Exam 2: Mar 28-30.
Covers Lects 9-15
No lab on week of exam.
Sign up for a slot!
Contact Dr. Schulte w Qs about signup.

Gammie Review session for Exam 2
Monday 3/26 7:00 PM+
in Loomis 144

What concepts did you find most difficult, or what would you like to be sure we discuss in lecture?

- List of comments from flipit

Recall this slide from lecture 5:

There will only be two types of forces we will study in PHYS 101

- *Type 2: Non-contact forces*: action at a distance forces.
  - In PHYS 101 we study the gravitational force (weight)
  - Near the earth's surface, $W = m_{object}\, g$
  - *Note: Any two masses will exert an attractive gravitational force on each other—more on that at a later lecture*

There is a more general form for the force between two masses

- Any two masses, m and M, exert an **attractive** gravitational force on each other given by:

$$F = \frac{GmM}{R^2}$$

Where $G = 6.7 \times 10^{-11} \frac{\mathrm{m}^3}{\mathrm{kg\ s}^2}$

- Near the earth's surface, $W = m_{object}\, g$
- So, notice that g must be equal to: $g = \frac{GM_{earth}}{R_{earth}^2}$

Let's check that this gives us value we recognize as g

- Let's substitute values: $g = \frac{GM_{earth}}{R_{earth}^2}$

$G = 6.7 \times 10^{-11} \frac{\mathrm{m}^3}{\mathrm{kg\ s}^2}$

Earth: Mass = 6×10^{24} kg

Radius = 6.4×10^{6} m.

Substituting we get:

$$g = \frac{GM_{earth}}{R_{earth}^2} = \frac{(6.7\times10^{-11})(6\times10^{24})}{(6.4\times10^{6})^2} = 9.81$$

Bingo!

Example: Weight of Object

- Calculate the gravitational force (i.e. weight) on a 3 kg book held 1 meter above the surface of the earth.

$$F_g = W = G\frac{M_{Earth}m_{object}}{r_{Earth}^2}$$

$$= \frac{\left(6.7\times10^{-11}\frac{\text{m}^3}{\text{kg s}^2}\right)(6\times10^{24}\ \text{kg})(3\ \text{kg})}{(6.4\times10^6+1)^2\ \text{m}^2}$$

$$= 29.4\,\frac{\text{kg m}}{\text{s}^2} = 29.4\ \text{Newtons (N)} \quad \left(1\,\frac{\text{kg m}}{\text{s}^2} = 1\ \text{N}\right)$$

Note: Since $g = 9.81\frac{m}{s^2}$

$$\text{W} = \text{m}g = (3\ kg)\left(9.81\frac{m}{s^2}\right)$$

$$= 29.4\ N$$

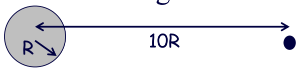
Recall that gravitational force is conservative, so there must be a potential energy expression

The gravitational potential energy between two masses, M and m, separated by a distance R is:

$$U = -\frac{GMm}{R}$$

Example

A meteor of mass 10^5 kg a distance of 10 earth radii from the center of the earth is moving toward earth at 250 m/s. How fast will it be moving when it strikes the surface of the earth?



$U = -\frac{GMm}{R}$

Big Idea: Gravity is a conservative force so mechanical energy is conserved:

Plan: 1. Set initial and final mechanical energies equal:

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

2. Solve for final velocity

When you solve for v_f you get:

$$v_f = \sqrt{v_i^2 + 2\left(\frac{9}{10}\right)\frac{GM_E}{R_E}}$$

And when you substitute values for v_i, G, M_E and R_E you get:

$$v_f = 10{,}634\ m/s = 23{,}788 \text{ mph}$$

Fun facts:

An asteroid, 6 miles across, hit the earth year the Yucatan peninsula 65 million years ago and wiped out the dinosaurs, along with ¾ of all species living on earth.

Another asteroid, 23 miles across, hit the earth 3.26 billion years ago. It shook the earth for ½ hour and caused the oceans to boil.