Section 1.3. Mass and Force
Section 1.4. First and Second Laws

WHAT IS MASS?

- *Is mass the same as weight?* You know from PHY 183 that mass and weight are different; but they are also related.
- It is clear that they must be different, because they have different ***units.***
- SI unit of mass = kilogram (kg);
- SI unit of weight = newton (N);
  N is a ***derived unit*** = kg m /s^2.

How do we measure mass?
We measure mass with balances.
The most familiar kind of balance is a *gravitational balance* .

We balance the sample (whose mass we wish to measure) against some standard masses (that are already known).

However, *the gravitational balance actually measures weight!*

Mass and Weight

Recall from PHY 183:

- Weight =
  the magnitude of the force of Earth's gravity acting on the object = w ;

- Weight = mass × g

where g = the acceleration due to gravity at the position of the object;

$$w = m\,g \qquad ;$$

or, $m = w/g$.

g is not exactly constant, but it is approximately constant over the surface of the Earth.

$$g = 9.81\ \text{m/s}^2 \quad \text{(approximate)}$$

Because g is "≈ constant" we have this approximate proportionality,

$$w \propto m\,.$$

Thus comparing the *weights* on a gravitational balance is the same as comparing the *masses* **(approximately)**

The inertial balance

(really just an academic exercise)

Can you measure ***mass*** in deep space, where g = 0?

I.e., *can you measure mass without using weight?*

See Figure 1.2.

Figure 1.2

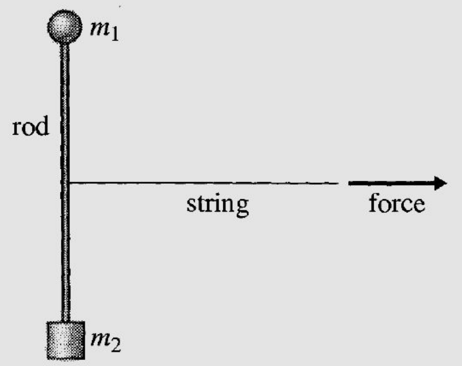


Figure 1.2 An inertial balance compares the masses m_1 and m_2 of two objects that are attached to the opposite ends of a rigid rod.

If the masses are equal, then pulling the string (**half way position**) will produce equal accelerations.

∴ we can measure the *sample* mass by comparing it to a known *standard* mass.

What is a kilogram?

Here is a picture of the International Prototype of the Kilogram (**IPK**)

It's a cylinder manufactured from a platinum–iridium alloy, 39.17 mm in both diameter and height; its edges have a four-angle (22.5°, 45°, 67.5° and 79°) chamfer to minimize wear.

In principle, masses are measured by comparison to the prototype kg, using balances.

In practice, the comparison is made to calibrated mass standards.

In everyday practice, *if accuracy is not important*, we measure the weight and divide by g.

How is this related to our study of mechanics?

The inertial balance is based on Newton's second law.

!! READ SECTION 1.4 !!

- **Newton's first law of motion**

  A body in motion remains in motion with constant velocity if the net force acting on the body is 0. A body at rest remains at rest.

- Newton inherited this law from Galileo.

- Kepler (a contemporary of Galileo) called it "***inertia***" – the Latin word for "laziness".

Taylor's statement: "In the absence of forces, a particle moves with constant velocity."

Merriam-Webster Dictionary

inertia (*physics*) *: a property of matter by which something that is not moving remains still and something that is moving goes at the same speed and in the same direction until another thing or force affects it.*

mass (*physics*) *: the property of a body that is a measure of its inertia and that is commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field.*

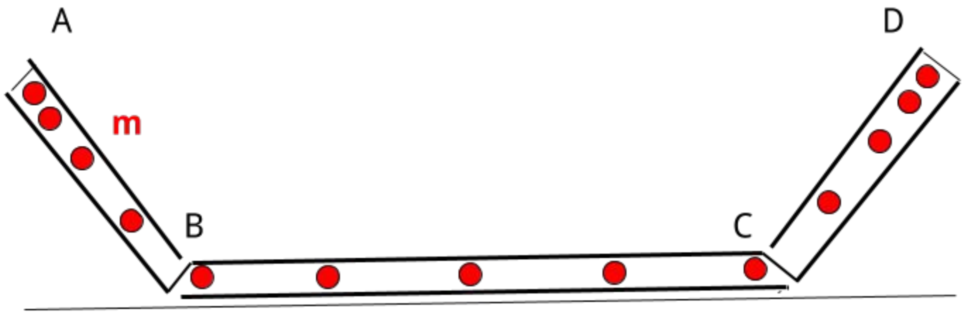
Mass is the quantitative measure of inertia.

- **Newton's second law of motion**

If net force $\mathbf{F}$ acts on a body with mass m, then the acceleration of the body is $\mathbf{a} = \mathbf{F}/m$.

This is familiar from PHY 183.

AN EXAMPLE OF <u>NEWTON'S FIRST LAW</u>



- MASS m SLIDES WITHOUT FRICTION ON THE SURFACE, IN EARTH'S GRAVITY.
- RELEASE m FROM REST AT POINT A, AND CATCH IT AT POINT D.
- <u>NEWTON'S FIRST LAW</u>: FROM B TO C THE VELOCITY IS CONSTANT, BECAUSE THE NET FORCE IS 0.

AN EXAMPLE OF <u>NEWTON'S FIRST LAW</u>

WHY IS EVERY DAY 24 HOURS LONG?

Comments. Taylor ends Section 1.4 with some comments, which are easily overlooked. Read carefully—these are fundamental to mechanics:

★ Differential equations

Newton's second law is a differential equation,

$$\mathbf{a} = \ddot{\mathbf{r}} = \mathbf{F}(\mathbf{r}) / m$$

($\ddot{\mathbf{r}}$ *is a notation for* $d^2\mathbf{r}/dt^2$)

That's why Newton invented calculus—to use it in mechanics.

★ Inertial frames

Newton's first and second laws of motion are true in inertial frames. Now, what is an inertial frame?

- An inertial frame is a frame of reference (think of a coordinate system) in which Newton's first and second laws of motion are true.
- That seems to be an example of circular reasoning. Maybe it would be better to say, an inertial frame is not a noninertial frame. But then we'd need to define a noninertial frame.
- Think of it this way: an inertial frame is at rest with respect to the whole universe.
- OR, A noninertial frame is accelerating with respect to the universe.
- As a practical matter, the Earth's surface is an inertial frame (only actually it isn't) and any frame of reference that moves with constant velocity w.r.t. the Earth is an inertial frame.

So read pages 15 – 17.

Homework Assignment #1
Instructions

- The due date is Friday, September 9.
- Homework solutions must be handed in in class.
- Homework solutions submitted by e-mail will be deleted.
- Homework solutions that are handed in late are not eligible for full credit, unless you have a valid reason for being late (you must document the reason for being late).

Staple the cover sheet, with answers where indicated, in front of your solutions.

Homework Assignment #1

due in class, Friday Sept. 9

[1] Problem 1.3 *

[2] Problem 1.5 *

[3] Problem 1.18 **

[4] Problem 1.24 *

[5] Problem 1.30 *

Use the cover sheet !

Be sure to get these two handouts:

1. ***Course description***
2. ***Cover sheet for H.W.A. #1***

Quiz

Define *"inertia"*.