PHY131H1F - Class 10

Today:

- Equilibrium
- Mass, Weight, Gravity

Which of the following objects described below is in *dynamic equilibrium*?

A. A 100 kg barbell is held *at rest* over your head.

B. A steel beam is lifted upward at *constant speed* by a crane.

C. A baseball is flying through the air and *air resistance is negligible*.

D. A steel beam is being lowered into place. It is *slowing down*.

E. A box in the back of a truck doesn't slide *as the truck is slowing down*.

Last day I asked at the end of class:

A basketball and a tennis ball are in freefall.

1. Which, if either, has the larger **mass**?

ANSWER: The basketball.

2. Which, if either, experiences the larger **force of gravity**?

ANSWER: The basketball. ($F_g = mg$)

3. Which, if either, experiences the larger **acceleration**?

ANSWER: Neither. $a_y = -g$ for both.

4. Which, if either, has the larger **weight**?

ANSWER: Neither. They are both "weightless".

Preparation for Practicals this week:

- Take a ride on the Burton Tower elevators!
- All 4 elevators in the 14-storey tower of McLennan Physical Labs are equipped with a hanging spring-scale.
- It measures the upward force necessary to support a 500 g mass. (a.k.a. "weight")
- You may find that the measured weight of this object changes as you accelerate – check it out!

⚠ WARNING

- Newton's Laws only apply in a "inertial reference frames". They are not valid if your reference frame is accelerating!
- An **inertial reference frame** is one that is **not accelerating.**

- A car is driving at a steady speed on a straight and level road.

Quick quiz [1/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

- A car is driving at a steady speed up a 10° incline.

Quick quiz [2/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

- A car is speeding up after leaving a stop sign, on a straight and level road.

Quick quiz [3/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

- A car is driving at a steady speed around a curve on a level road.

Quick quiz [4/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

Equilibrium $\boxed{\Sigma\vec{F} = 0}$

- An important problem solving technique is to identify when an object is in equilibrium.
- An object has zero acceleration if and only if the net force on it is zero.
- This is called "equilibrium".
- If an object is in **vertical equilibrium** (ie it is confined to a stationary horizontal surface) then $(F_{net})_y = 0$. The sum of y-components of all forces = 0.
- If an object is in **horizontal equilibrium** (ie freefall) then $(F_{net})_x = 0$.

Gravity for the universe

It was Newton who first recognized that **gravity is an attractive, long-range force between *any* two objects.** Somewhat more loosely, gravity is a force that acts on mass. When two objects with masses m_1 and m_2 are separated by distance r, each object pulls on the other with a force given by Newton's law of gravity, as follows:

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{Gm_1m_2}{r^2} \qquad \text{(Newton's law of gravity)}$$

(Sometimes called "Newton's 4th Law", or "Newton's Law of Universal Gravitation")

Gravity for Earthlings

If you happen to live on the surface of a large planet with radius R and mass M, you can write the gravitational force even more simply as

$$\vec{F}_G = (mg, \text{straight down}) \qquad \text{(gravitational force)}$$

where the quantity g is defined to be:

$$g = \frac{GM}{R^2}$$

At sea level, $g = 9.83$ m/s^2.
At 39 km altitude, $g = 9.71$ m/s^2.

Gravity: $F_G = mg$ is just a short form!

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{Gm_1m_2}{r^2}$$

and

$$\vec{F}_G = (mg, \text{straight down})$$

are the same equation, with different notation!

The only difference is that in the second equation we have assumed that $m_2 = M$ (mass of the earth) and $r \approx R$ (radius of the earth).

Test 1 Marking

- You can find the percentage of your Test 1 mark under the My Grades link on portal.
- Your actual mark is this mark times 40 divided by 100.
- The free-form questions will be handed back to you in Practicals. The marks for each part are written there.
- If you subtract the sum of your free-form marks from the total mark on portal, you can figure out what you got on the multiple choice part.
- If you wish to look over the bubble-sheet you turned in for the multiple choice part, please go to MP129.
- If you are concerned about the marking of your test, you have until **Monday, October 22**, at 5:00pm, to take these concerns to the office of the Course Coordinator, Dr. Savaria (MP129). No request will be considered after that date.

Weight ≠ Weight ??!?

- Physics textbooks and physics teachers do not all agree on the definition of the word "weight"!
- Sometimes "weight" means the exact same thing as "force of gravity". That is ***not*** how Randall Knight uses the word. (I will follow Knight's definitions.)
- In Knight, "weight" means the magnitude of the *upward* force being used to support an object.
- **If the object is at rest** or moving at a constant velocity relative to the earth, then the object is in equilibrium. The upward supporting force exactly balances the downward gravitational force, so that weight = mg.

Weight - example

- When I stand on a scale in my bathroom it reads 185 pounds. 2.2 pounds = 9.8 Newtons, so this means the upward force on my feet when I am standing still is 185 lbs (9.8 N / 2.2 lbs) = 824 N.
- If I ride an elevator which is accelerating upward at 1.5 m/s^2, what is the upward force on my feet?
- [Take a wild guess first: **A:** 824 N, **B:** 950 N, **C:** 698 N, **D:** 0 N, **E:** –824 N]

Knight's Definition of weight Eq. 6.10, page 147:

The **weight** of an object is the reading of a calibrated spring scale on which the object is stationary. Weight is the result of weighing. The weight of an object with vertical acceleration a_y is

$$w = mg\left(1 + \frac{a_y}{g}\right)$$

Spring scale on an elevator

You are attempting to pour out 1.0 kg of flour, using a kitchen scale on an elevator which is accelerating upward at 1.5 m/s^2.

The amount of flour you pour will be

A. too much.

B. too little.

C. the correct amount.

Pan balance on an elevator

You are attempting to pour out 100 g of salt, using a pan balance on an elevator which is accelerating upward at 1.5 m/s^2. Will the amount of salt you pour be

A. Too much
B. Too little
C. The correct amount

Self-adjusting forces

- Gravity, F_G, has an equation for it which predicts the correct magnitude (it's always mg here on Earth).
- Normal force, Tension and Static friction are all self-adjusting forces: ***there is no equation for these!!***
- Normal force is whatever is needed to keep the object from crashing through the surface.
- Tension is whatever is needed to keep the string or rope from breaking.
- Static friction is whatever is needed to keep the object from slipping along the surface.
- In all these cases, you must draw a free-body diagram and figure out by using equilibrium and Newton's 2nd law what the needed force is.

Getting the piano on the truck

- A piano has a mass of 225 kg.

1. What force is required to push the piano upwards at a constant velocity as you lift it into the truck?
2. What force is required to push the piano up a frictionless ramp at a constant velocity into the truck? Assume the ramp is 3.00 m long and the floor of the truck is 1.00 m high? What is the normal force of the ramp on the piano?

Before Class 11 on Wednesday

- Please finish reading Chapter 6
- Take a ride on the Burton Tower elevators, do prep-work for Mechanics Module 3 Activity 2.
- Please read the rest of Knight **Chapter 6.**
- Something to think about:

Does friction always slow things down? Can friction ever speed things up?