PHY131H1F
University of Toronto

Class 10 Preclass Video
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Based on Knight 3rd edition
Ch. 6, Sections 6.1 – 6.3
pgs. 138 - 147

Sections 6.1 & 6.2

Equilibrium

- An object on which the net force is zero is in *equilibrium*
- If the object is at rest, it is in *static equilibrium*
- If the object is moving along a straight line with a constant velocity it is in *dynamic equilibrium*
- The requirement for either type of equilibrium is:

$$(F_{\text{net}})_x = \sum_i (F_i)_x = 0$$

$$(F_{\text{net}})_y = \sum_i (F_i)_y = 0$$

The concept of equilibrium is essential for the engineering analysis of stationary objects such as bridges.

PROBLEM-SOLVING STRATEGY 6.1 **Equilibrium problems**

MODEL Make simplifying assumptions. When appropriate, represent the object as a particle.

VISUALIZE

- Establish a coordinate system, define symbols, and identify what the problem is asking you to find. This is the process of translating words into symbols.
- Identify *all* forces acting on the object and show them on a free-body diagram.
- These elements form the **pictorial representation** of the problem.

SOLVE The mathematical representation is based on Newton's first law:

$$\vec{F}_{\text{net}} = \sum_i \vec{F}_i = \vec{0}$$

The vector sum of the forces is found directly from the free-body diagram.

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

Using Newton's Second Law

The essence of Newtonian mechanics can be expressed in two steps:

- The forces on an object determine its acceleration $\vec{a} = \vec{F}_{\text{net}}/m$, and
- The object's trajectory can be determined by using $\vec{a}$ in the equations of kinematics.

Problem-Solving Strategy: Dynamics problems

PROBLEM-SOLVING STRATEGY 6.2 **Dynamics problems**

MODEL Make simplifying assumptions.

VISUALIZE Draw a **pictorial representation.**

- Show important points in the motion with a sketch, establish a coordinate system, define symbols, and identify what the problem is trying to find.
- Use a motion diagram to determine the object's acceleration vector $\vec{a}$.
- Identify all forces acting on the object *at this instant* and show them on a free-body diagram.
- It's OK to go back and forth between these steps as you visualize the situation.

Problem-Solving Strategy: Dynamics problems

PROBLEM-SOLVING STRATEGY 6.2 **Dynamics problems**

SOLVE The mathematical representation is based on Newton's second law:

$$\vec{F}_{net} = \sum_i \vec{F}_i = m\vec{a}$$

The vector sum of the forces is found directly from the free-body diagram. Depending on the problem, either

- Solve for the acceleration, then use kinematics to find velocities and positions; or
- Use kinematics to determine the acceleration, then solve for unknown forces.

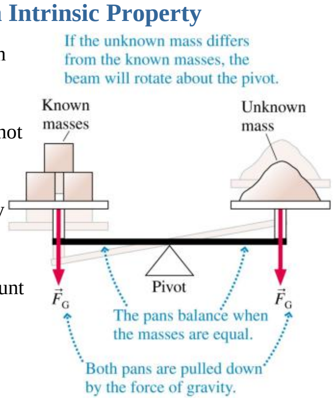
ASSESS Check that your result has the correct units, is reasonable, and answers the question.

Exercise 22

Section 6.3

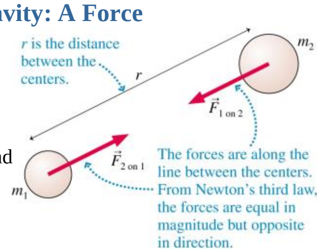
Mass: An Intrinsic Property

- A *pan balance*, shown in the figure, is a device for measuring **mass**
- The measurement does not depend on the strength of gravity
- Mass is a scalar quantity that describes an object's inertia
- Mass describes the amount of matter in an object
- **Mass is an intrinsic property of an object**



Gravity: A Force

- Gravity is an attractive, long-range force between any two objects
- The figure shows two objects with masses m_1 and m_2 whose centers are separated by distance r
- Each object pulls on the other with a force:

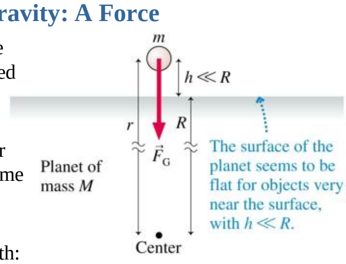


$$F_{1\ on\ 2} = F_{2\ on\ 1} = \frac{Gm_1 m_2}{r^2} \quad \text{(Newton's law of gravity)}$$

- where $G = 6.67 \times 10^{-11}$ N m^2/kg^2 is the gravitational constant

Gravity: A Force

- The gravitational force between two human-sized objects is very small
- Only when one of the objects is planet-sized or larger does gravity become an important force
- For objects near the surface of the planet earth:



$$\vec{F}_G = \vec{F}_{planet\ on\ m} = \left(\frac{GMm}{R^2}, \text{straight down}\right) = (mg, \text{straight down})$$

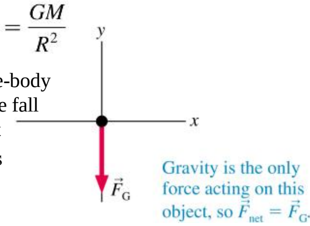
- where M and R are the mass and radius of the earth, and $g = 9.80$ m/s^2

Gravity: A Force

- The magnitude of the gravitational force is $F_G = mg$, where

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

- The figure shows the free-body diagram of an object in free fall near the surface of a planet
- With $\vec{F}_{net} = \vec{F}_G$, Newton's second law predicts the acceleration to be:

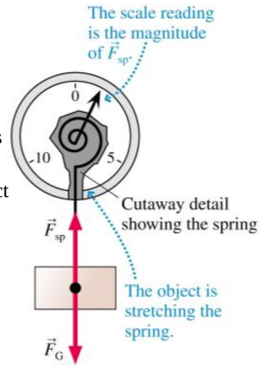


$$\vec{a}_{free\ fall} = \frac{\vec{F}_{net}}{m} = \frac{\vec{F}_G}{m} = (g, \text{straight down})$$

- All objects on the same planet, regardless of mass, have the same free-fall acceleration!

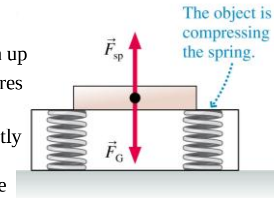
Weight: A Measurement

- You weigh apples in the grocery store by placing them in a *spring scale* and stretching a spring
- The reading of the spring scale is the magnitude of F_{sp}
- We define the **weight** of an object as the reading F_{sp} of a calibrated spring scale on which the object is stationary
- Because F_{sp} is a force, weight is measured in newtons



Weight: A Measurement

- A bathroom scale uses compressed springs which push up
- When any spring scale measures an object at rest, $\vec{F}_{net} = \vec{0}$
- The upward spring force exactly balances the downward gravitational force of magnitude *mg*:



$$F_{sp} = F_G = mg$$

- Weight is defined as the magnitude of F_{sp} when the object is at rest relative to the stationary scale:

$$w = mg \qquad \text{(weight of a stationary object)}$$

Weight: A Measurement

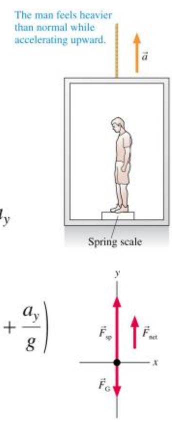
- The figure shows a man weighing himself in an accelerating elevator
- Looking at the free-body diagram, the *y*-component of Newton's second law is:

$$(F_{net})_y = (F_{sp})_y + (F_G)_y = F_{sp} - mg = ma_y$$

- The man's weight as he accelerates vertically is:

$$w = \text{scale reading } F_{sp} = mg + ma_y = mg\left(1 + \frac{a_y}{g}\right)$$

- You weigh *more* as an elevator accelerates upward!



Weightlessness

- The weight of an object which accelerates vertically is

$$w = \text{scale reading } F_{sp} = mg + ma_y = mg\left(1 + \frac{a_y}{g}\right)$$

- If an object is accelerating downwards with $a_y = -g$, then $w = 0$
- An object in free fall *has no weight!*
- Astronauts in orbiting the earth are also weightless
- Does this mean that they are in free fall?

Astronauts are weightless as they orbit the earth.