Dynamics
Laws of Motion
Forces & Problem Solving

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Jan 27, 2020

Last time

- Newton's third law
- action-reaction pairs
- forces fundamentally

Overview

- fields
- gravity
- tension
- equilibrium

Fields

field

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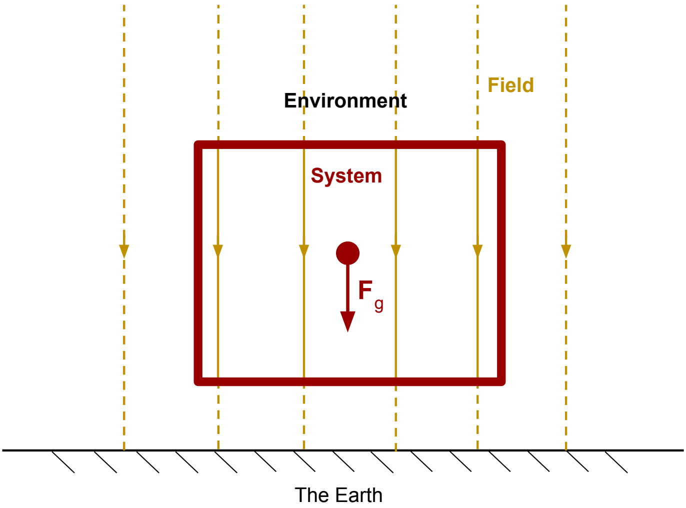
Fields were first introduced as a calculation tool. A force-field can be used to identify the force a particular particle will feel at a certain point in space and time based on the other objects in its environment that it will interact with.

We do not need a description of the sources of the field to describe what their effect is on our particle.

Fields

To be clear: When we adopt a field model of force interactions we separate two interacting objects, placing one in the *system* and the other in the *environment*.



Examples of Fields

Gravity and the electrostatic force have associated fields.

$$\vec{\mathbf{g}} = -9.8\,\hat{\mathbf{j}}\ \mathrm{N/kg}, \quad \text{the gravitational field strength.}$$

$$\vec{\mathbf{F}}_G = m\vec{\mathbf{g}} \qquad \vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$$

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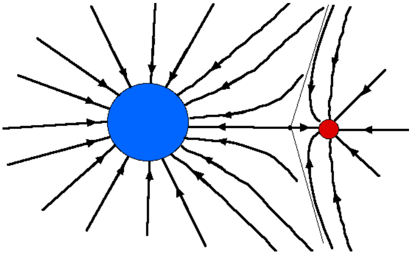
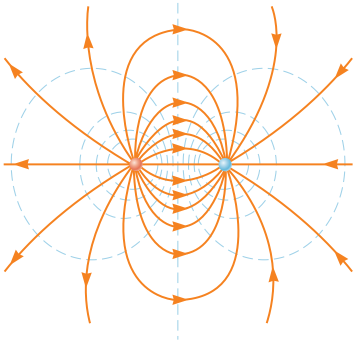
Representing Fields

Fields are drawn with lines showing the direction of force that a test particle will feel at that point. The density of the lines at that point in the diagram indicates the approximate magnitude of the force at that point.

Gravitation:

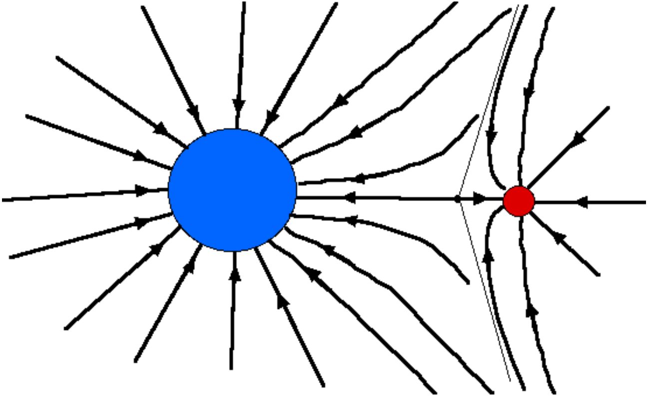


Electrostatic:



Examples of Fields

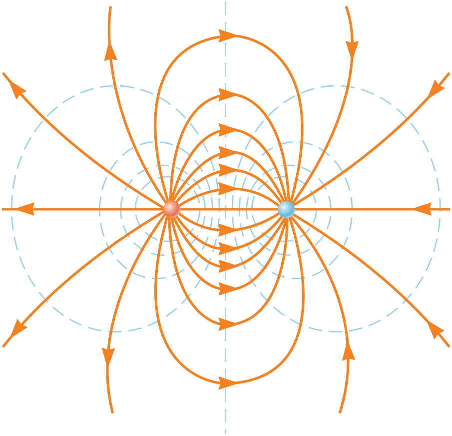
The gravitational field caused by the Sun-Earth system can be represented as:



[1]Figure from http://www.launc.tased.edu.au

Examples of Fields

The electrostatic field caused by an electric dipole system can be represented as:



[1]Figure from Serway & Jewett

Some types of forces

We will review some kinds of forces and how they behave, and consider some examples illustrating them.

Some types of forces

Gravitation

The force that massive objects exert on one another.

Newton's Law of Universal Gravitation

$$F_G = \frac{Gm_1 m_2}{r^2}$$

for two objects, masses m_1 and m_2 at a distance r.

$G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}.
(Challenge: check the units of G.)

Some types of forces

Gravitation cont'd

For the moment, we will care about this force in that it gives objects weight, F_g.

$$F_g = mg$$

and

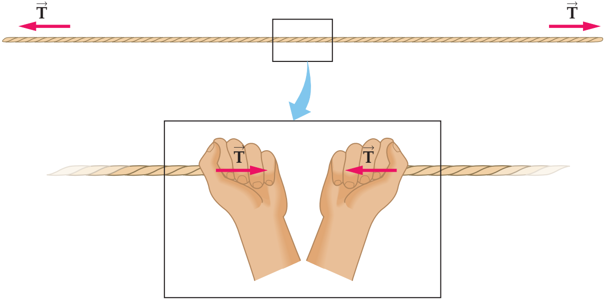
$$g = \frac{GM_{\text{Earth}}}{R_{\text{Earth}}^2}$$

The force $\vec{\mathbf{F}}_g$, acts downwards towards the center of the Earth.

Some types of forces

Tension

The force exerted by a rope or chain to suspend or pull an object with mass.



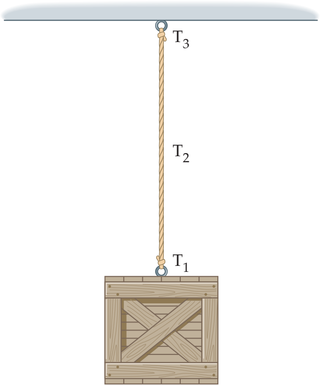
Tension acts in both directions along the rope, so when asked for a tension, typically one just gives a magnitude.

[1] Figure from James S. Walker, "Physics".

Some types of forces: Tension

If a rope is "light" (massless) the tension is the same everywhere in the rope.

If the rope is has mass the tension can vary alongs the rope.



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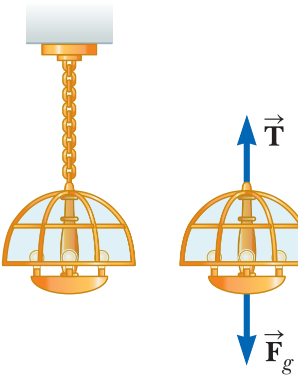
Definition: Equilibrium

Equilibrium

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



Equilibrium

We say that an object is *in equilibrium* when there is no net force acting on it. Forces may act on the object, but the sum of the force vectors is zero.

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That means, in particular, that

$$F_{x,\text{net}} = \sum_i F_{x,i} = 0$$

and

$$F_{y,\text{net}} = \sum_i F_{y,i} = 0$$

(Works for any pair of perpendicular directions you might choose.)

Equilibrium

Usually, you know an object is in equilibrium because you observe (or are told) something about its **motion**.

$$\vec{\mathbf{F}}_{\text{net}} = 0 \;\Leftrightarrow\; \vec{\mathbf{a}} = 0$$

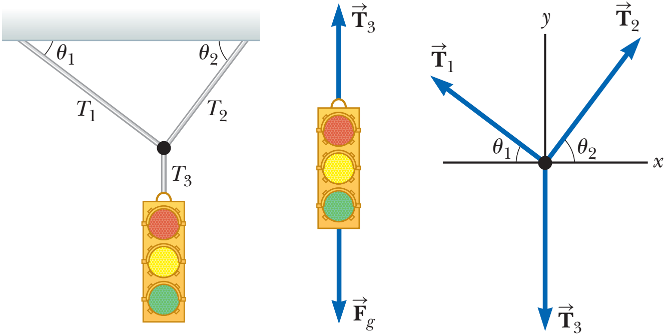
If an object moves with constant velocity, it is in equilibrium.

Static Equilibrium occurs when an object is at rest and remaining at rest.

$$\vec{\mathbf{a}} = 0 \;, \quad \vec{\mathbf{v}} = 0$$

Statics with Tensions

Example: A traffic light weighing 200 N is suspended by two light cables, as shown in the diagram, so that $\theta_1 = 30°$ and $\theta_2 = 45°$.



Find the tensions T_1 and T_2.

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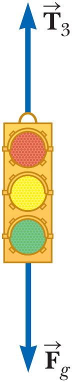

Static $\Rightarrow$ $\vec{\mathbf{F}}_{\text{net}} = 0$ for the traffic light.

<u>traffic light, y-direction:</u>

$$
\begin{aligned}
F_{\text{net},y} &= m\cancelto{0}{a_y} \\
T_3 - F_g &= 0 \\
T_3 &= F_g = 200N \qquad (1)
\end{aligned}
$$

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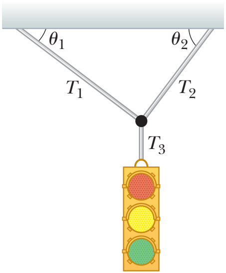

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(solution continues next lecture...)

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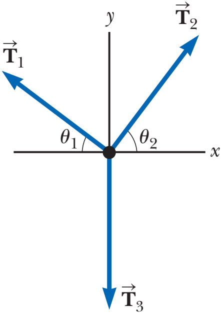

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(solution continues next lecture...)

Summary

- fields
- gravity
- tension
- equilibrium

(Uncollected) Homework Serway & Jewett,

- Ch 5, onward from page 138. Probs: 21, 33, 37