Physics 2514

Lecture 11

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Goals

We will discuss inertial frames of reference, then move on to discuss weight (the force of gravity) acting on an object.

We then move on to a discussion of how to solve force problems applying Newton's laws of motion. We will concentrate on problems that involve equilibrium.

Newton's Laws of Motion

1) An object that is at rest will remain at rest, or an object that is moving will continue to move (in a straight line) with constant velocity, if and only if the net force acting on the object is zero.

2) An object of mass m subjected to forces $\vec{\mathbf{F}}_1, \vec{\mathbf{F}}_2, \vec{\mathbf{F}}_3, \ldots$ will undergo an acceleration $\vec{\mathbf{a}}$ given by

$$\vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}} \quad \text{where} \quad \vec{\mathbf{F}}_{\text{net}} = \sum_{i=1}^{n} \vec{\mathbf{F}}_i$$

3) To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal and directed to contrary parts.

Newton's First Law of Motion

Newton's first law defines what we mean by a force, "it is what causes an object to change its velocity". It also specifies under what conditions Newton's laws of motion hold.

Newton's laws hold only in inertial frames of reference.

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Reference Frame

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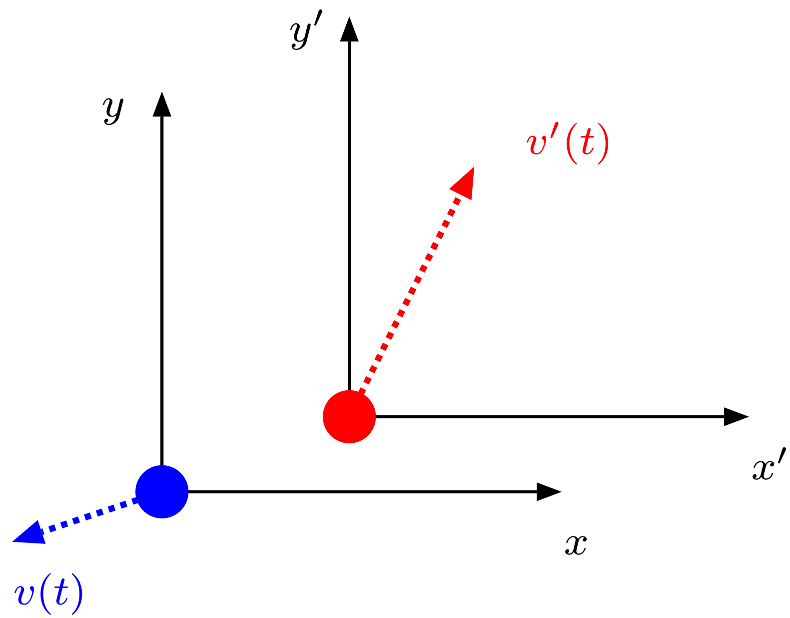


If $v(t)$ or $v'(t)$ are constant, then the primed or unprimed frame is an inertial reference frame

Inertial Reference Frames

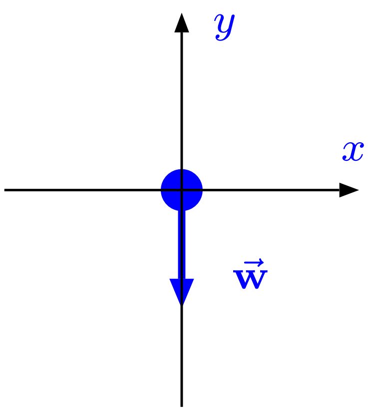
- An inertial reference frame is one in which Newton's laws hold;
  - Consider a person walking at a constant velocity. Throws an object straight up it returns to his hand sometime later inertial frame;
  - Next consider a person walking at a constant velocity. Throws an object straight up, then accelerates the object does not return to his hands non-inertial frame, must introduce fictitious force to explain motion:
- Simple definition of inertial frame:
  - Frame that is not accelerating relative to the most distant stars (the Earth is only an approximate inertial frame).

Mass and Weight

According to Galileo, all objects fall toward the Earth with the same acceleration near its surface.

According to Newton, an object has an acceleration given by $\vec{\mathbf{a}} = \vec{\mathbf{F}}_{\text{net}}/m$

Based on these two statements, the force of gravity on an object near the surface of the Earth is:



Earth

$$\left.\begin{array}{l} \vec{\mathbf{a}} = -g\,\hat{\mathbf{j}} \\ \vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{w}} = m\vec{\mathbf{a}} \end{array}\right\} \quad \Rightarrow \quad \vec{\mathbf{w}} = -mg\,\hat{\mathbf{j}}$$

Mass and Weight

Weight is not a property of an object, it depends on the force of gravity. Weight of a given object on the moon is $1/6$ what it is on Earth.

Mass is a property of the object. It has the same value everywhere. Mass is a scalar, weight is a vector.

Clicker

The space shuttle orbits the Earth while traveling at a constant speed in 90.35 minutes at an altitude of 290 km. Which of the following statements is true:

A) The shuttle astronauts have zero mass;

B) The shuttle astronauts have zero weight;

C) The shuttle astronauts have a nonzero weight;

D) The space shuttle has nonzero weight but the astronauts have zero weight;

E) None of the above.

Equilibrium

Let's first consider problems of static equilibrium

- Equilibrium corresponds to the case that the object has zero net force acting on it $\vec{\mathbf{F}}_{\text{net}} = 0$
- Two types of equilibrium conditions
  - Static equilibrium corresponds to the case when the object is at rest
  - Dynamic equilibrium corresponds to the case when the object moves at a constant velocity
  - Both correspond to $\vec{\mathbf{F}}_{\text{net}} = 0$.

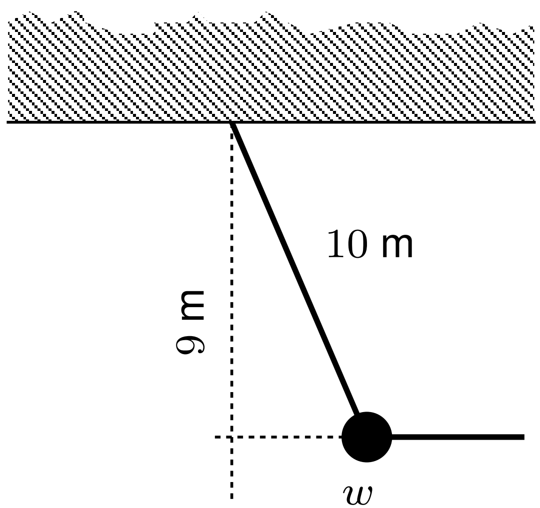
Solving Problems

To solve problems using Newton's laws of motion, we will follow the same problem solving procedure as for the case of kinematics.

- Rewrite the problem in a couple of sentences;
  1. State the situation;
  2. What variables are we solving for;
- Draw a force diagram Free Body Diagram
- State the known and unknown variables;
- Solve the problem algebraically;
- Substitute numbers into the problem.

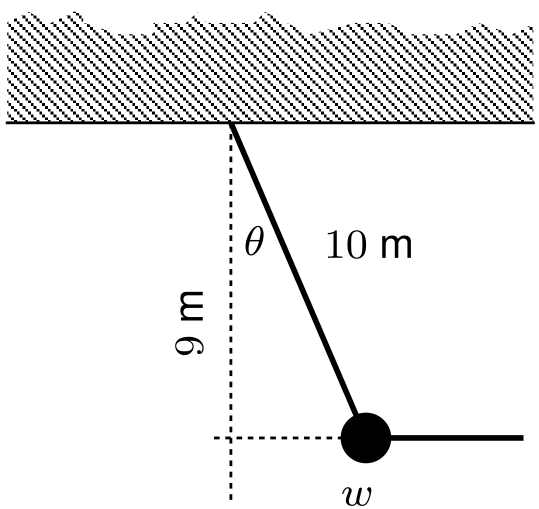
Example

Consider a 1000 kg bucket attached to a 10 m long chain that is hanging from a beam. The bucket is pulled horizontally by a cable until it is raised 1 m above its lowest point. What is the tension in the cable in order to hold the bucket in this position. *Assume that the mass of the chain and cable are negligible compared to the mass of the bucket.*

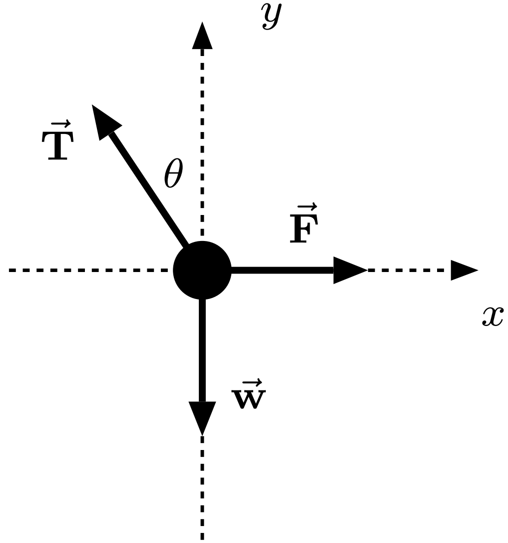


Solution

Brief description A 1000 kg object in static equilibrium is attached to a chain. The chain makes an angle $\theta = \cos^{-1}(9/10)$ with the vertical. What horizontal force is required to hold this configuration.



Free body diagram



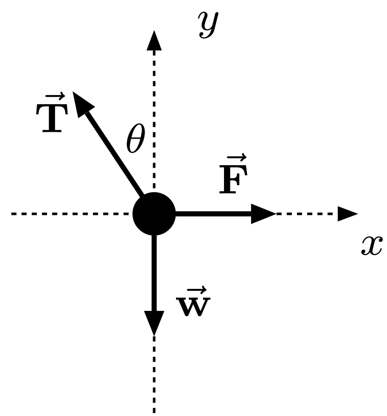
Solution

Known

$\cos\theta = 9/10$

$\sin\theta = \sqrt{19}/10$

$w = mg = 9800$ N



Unknown

$\vec{\mathbf{T}}$, $\vec{\mathbf{F}}$

Equations:

$$\left.\begin{aligned}\sum F_x = F - T_x = F - T\sin\theta = 0\\ \sum F_y = T_y - w = T\cos\theta - w = 0\end{aligned}\right\} \Rightarrow \left\{\begin{aligned}F = T\sin\theta\\ T = w/\cos\theta\end{aligned}\right\}$$

$$\Rightarrow \quad F = w\tan\theta = 9800(\sqrt{19}/9) \text{ N}$$

Assignment

Review for exam. Prepare questions for lecture and discussion sections