Mechanics
More About Newton's 3rd Law
Some Types of Forces

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Last time

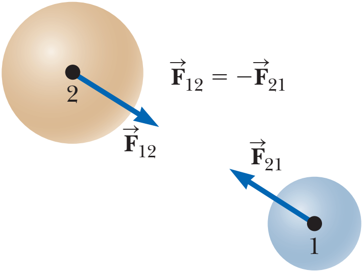
- Newton's second law examples
- Newton's third law
- action-reaction pairs of forces

Overview

- more about action-reaction pairs of forces
- some types of forces

Defining a System

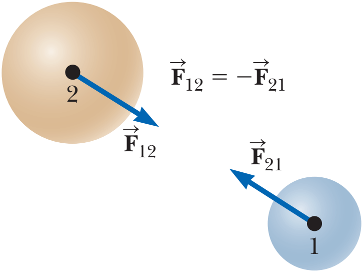
Consider these particles which exert a force on each other:



They are attracted. Each will accelerate toward the other.

Defining a System

Consider these particles which exert a force on each other:



They are attracted. Each will accelerate toward the other.

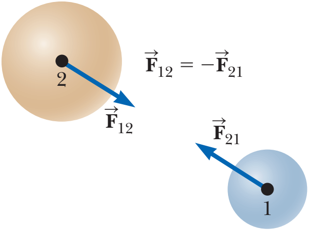
But wait: do the forces cancel?

$$\mathbf{F}_{1\to2} = -\mathbf{F}_{2\to1} \;\Rightarrow\; \mathbf{F}_{1\to2} + \mathbf{F}_{2\to1} = 0$$

Is the net force zero? How can they each accelerate?

Defining a System

Consider these particles which exert a force on each other:



Is the net force zero?

No! The forces act on different objects. To find if particle 1 accelerates, we find the net force **on particle 1**. We do not consider forces on particle 2.

The only force on particle 1 is $\mathbf{F}_{2\to1}$, so the net force is not zero: it accelerates.

Action and Reaction

Why when we fire a cannon does the cannon ball move much faster forward than the cannon does backwards?

Why when we drop an object does it race downwards much faster than the Earth comes up to meet it?

Action and Reaction

Why when we fire a cannon does the cannon ball move much faster forward than the cannon does backwards?

Why when we drop an object does it race downwards much faster than the Earth comes up to meet it?

The masses of each object are very different!

From Newton's second law

$$a = \frac{F}{m}$$

If m is smaller, a is bigger. If m is very, very big (like the Earth), the acceleration is incredibly small.

Force Diagrams

Question. Do the two forces shown in the diagram that act on the monitor form an action-reaction pair under Newton's third law?

(A) Yes.

(B) No.

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(A) Yes.

(B) No. ←

Some types of forces: Gravitation and Weight

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

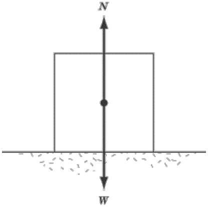
$$F_g = W = mg$$

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

Some types of forces

The Normal Force

The normal force supports and object sitting on a surface. It acts in a direction perpendicular to the surface.



For an object of weight **W** sitting on a level surface (that is not accelerating), the *normal force*, **N** is

$$\mathbf{N} = -\mathbf{W}$$

Be careful! There are many cases in which the above equation is not true!

[1] Figure from www.sparknotes.com

The Normal Force

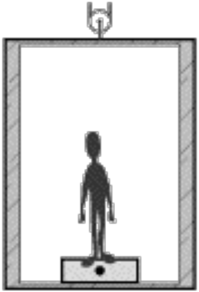
The normal force supports an object that sits on a surface, but its magnitude is different in different circumstances.

In general, one needs to work out what it will be in each problem.

Some cases where the normal force is different than the weight of an object are:

- the object is in an accelerating elevator.
- the object sits on an incline.

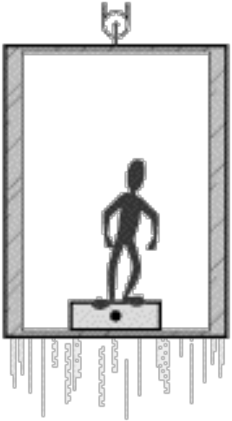
Elevator Problems



$$\mathbf{a} = 0$$

Elevator is at rest or moving with constant velocity. You feel the same as you normally do. Your weight and normal force are both of magnitude mg.

Elevator Problems

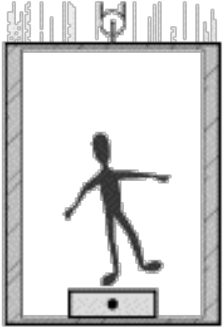


$\mathbf{a} = +a\,\mathbf{j}$ (a is a positive number)

Elevator could be moving upward increasing speed **or** downward decreasing speed. You feel as if your weight has increased.

Your weight is $-mg\,\mathbf{j}$, but the normal force is $\mathbf{n} = m(g + a)\,\mathbf{j}$.

Elevator Problems



$\mathbf{a} = -a\,\mathbf{j}$ (a is a positive number)

Elevator could be moving upward and slowing down **or** moving downward increasing speed. You feel as if your weight has decreased.

Your weight is $-mg\,\mathbf{j}$, but the normal force is $\mathbf{n} = m(g - a)\,\mathbf{j}$.

The Normal Force

The normal force supports an object that sits on a surface, but its magnitude is different in different circumstances.

In general, one needs to work out what it will be in each problem.

Some cases where the normal force is different than the weight of an object are:

- the object is in an accelerating elevator.
- the object sits on an incline.

Object on an Incline

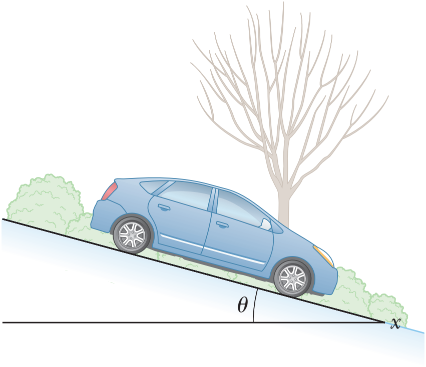
Problems with an object placed on an incline often require us to find the net force on the object or its acceleration.

[2] Figures from Serway & Jewett

Object on an Incline

Problems with an object placed on an incline often require us to find the net force on the object or its acceleration.

Consider a car on a frictionless driveway.[1] (Or free to roll, with frictionless, massless wheels.)



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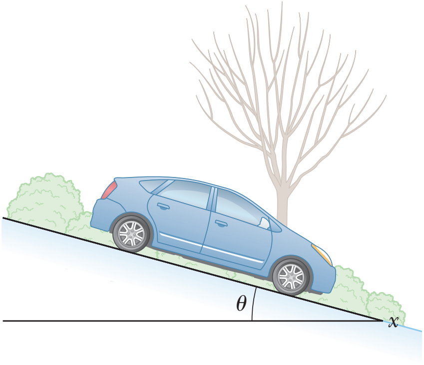
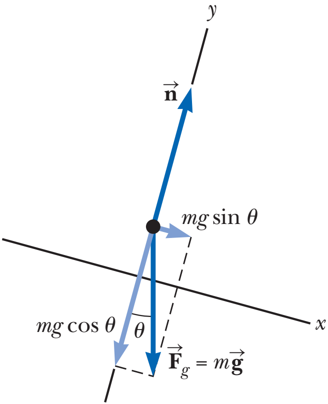
Object on an Incline

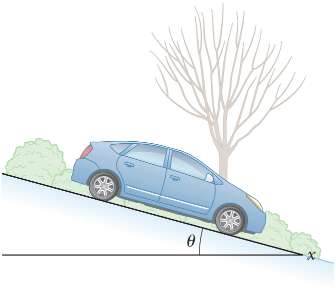


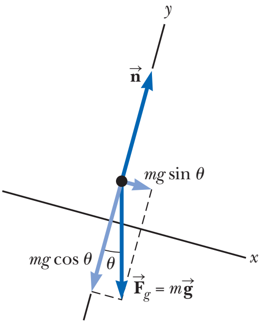


The forces acting on the car: weight and normal force.

In this case, it is useful to pick a coordinate system that is rotated: the x axis points along slope, the y axis perpendicular to the slope.

Object on an Incline



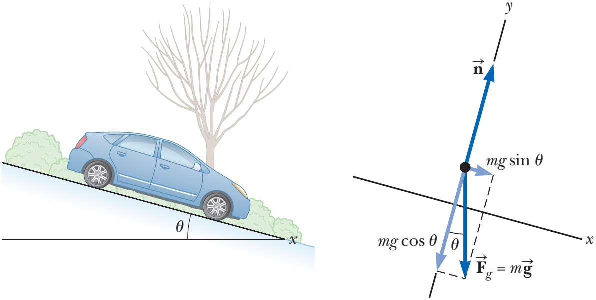


The forces acting on the car: weight and normal force.

The weight acts downwards and the normal force acts in a direction perpendicular to the inclined surface.

The normal force has a magnitude such that it cancels out the component of the weight perpendicular to the surface.

Object on an Incline



So, the forces in the (tilted) y-direction cancel:

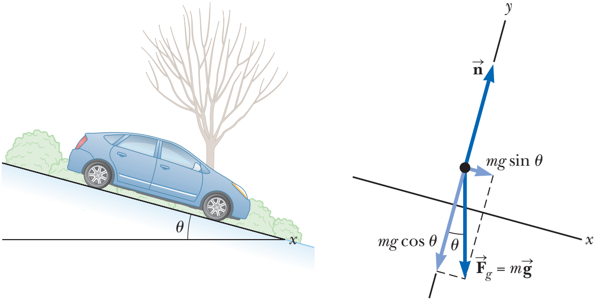
$$F_y = n - mg\cos\theta = 0$$

Rearranging:

$$n = mg\cos\theta$$

If $\theta > 0$ (it is an incline, not a flat surface), the normal force will be less than the weight, mg.

Object on an Incline



In the (tilted) x-direction, there is only a component from the weight:

$$F_x = mg\sin\theta$$

$\Rightarrow \quad \mathbf{F}_{\text{net}} = (mg\sin\theta)\mathbf{i}$

$\Rightarrow \quad \mathbf{a} = (g\sin\theta)\mathbf{i}$

Incline Example

A 65-kg skier speeds down a trail, as shown. The surface is smooth and inclined at an angle of 22° with the horizontal.
(a) Find the direction and magnitude of the net force acting on the skier.
(b) Does the net force exerted on the skier increase, decrease, or stay the same as the slope becomes steeper? Explain.

[1]Walker, Ch 5, #32.

Summary

- more about action-reaction pairs
- types of forces
- normal force

Test Thursday, Oct 18.

Homework

- (same as yesterday) Ch 5 Ques: 9; Probs: 17, 29, 31, 33, 39, 45, 49, 53, 55, 87