Introduction to Mechanics
Dynamics
Forces
Applying Newton's Laws

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Last time

- types of forces: normal force
  - elevators and acceleration

Overview

- types of forces: normal force
    - inclines
- tension

Elevator Problem

When you lift a bowling ball with a force of 82 N, the ball accelerates upward with an acceleration a. If you lift with a force of 92 N, the ball's acceleration is $2a$. Find (a) the weight of the bowling ball, and (b) the acceleration a.

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:

- there are other forces with components perpendicular to the surface.
- the object is in an accelerating elevator.
- the object sits on an incline.

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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.

[1]Figures from Serway & Jewett

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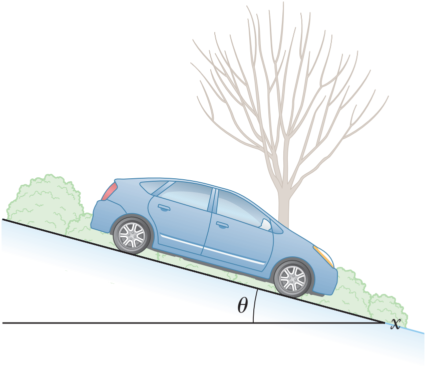
Consider a car on a frictionless driveway.[1] (Or free to roll, with frictionless, massless wheels.)



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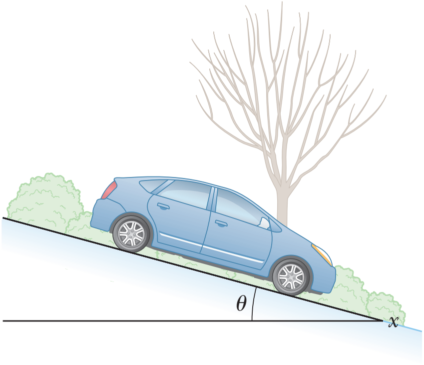
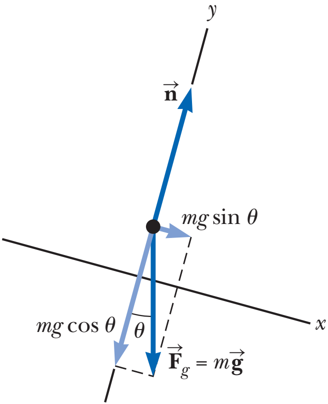
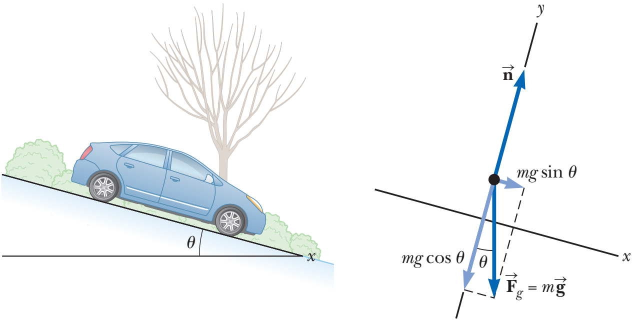




The forces acting on the car: weight and normal force.

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.

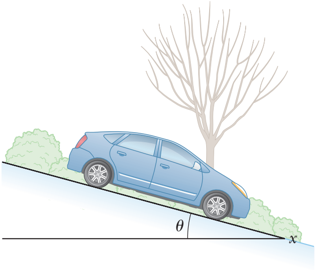
Object on an Incline

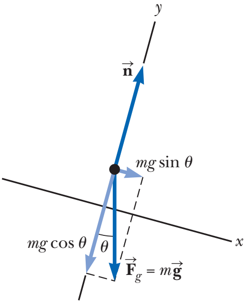


The forces acting on the car: weight and normal force.

Imagine the car starts from rest. If it were to accelerate off the surface, the normal force would go to zero immediately. The car also cannot sink (accelerate) into the surface. $\Rightarrow a_y = 0$.

Object on an Incline

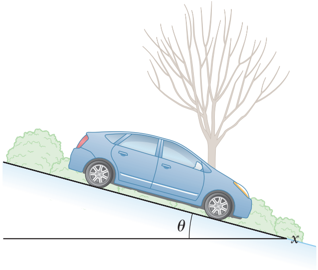


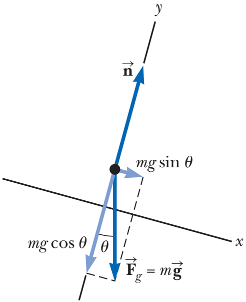


So, the forces in the (tilted) y-direction cancel:

$$\begin{aligned} F_{\text{net},y} &= m\cancel{a_y}^{\,0} \\ n - mg\cos\theta &= 0 \end{aligned}$$

Object on an Incline





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$$
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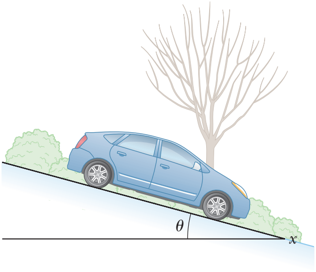
\end{aligned}
$$

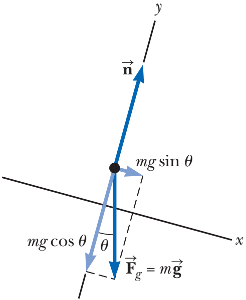
Rearranging:

$$n = mg\cos\theta$$

If $\theta > 0$ the normal force will be less than the weight, mg.

Object on an Incline





In the (tilted) x-direction:

$$\begin{aligned} F_{\text{net},x} &= ma_x \\ \cancel{m}g \sin \theta &= \cancel{m}a_x \end{aligned}$$

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

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

Incline Example

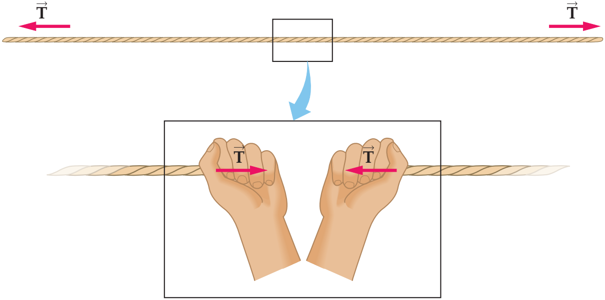
A 65-kg skier speeds down a trail, as shown. The surface is smooth and inclined at an angle of 22° with the horizontal.
(a) Find the direction and magnitude of the net force acting on the skier.
(b) Does the net force exerted on the skier increase, decrease, or stay the same as the slope becomes steeper?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

[1] Walker, Ch 5, #32.

Some types of forces

Tension

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



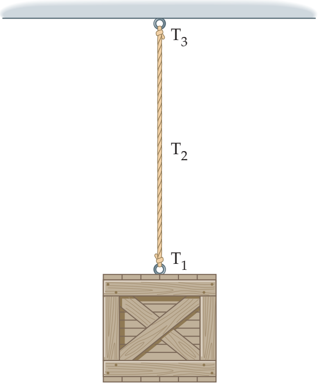
Problems involving tensions often require solving systems of vector equations.

[1] Figure from Walker, "Physics".

Some types of forces

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.



(See also example 5-5 on pg 126 and 6-5 of the textbook.)

[1]Figure from Walker, "Physics".

Summary

- the normal force
- normal force: elevators
- normal force: inclines
- tension

Homework

Walker Physics:

- Ch 5, Problems: 25, 27, 45, 49, 51 (inclines)