Lecture 6: Newton's Third Law

- Newton's 3rd Law
- Action-reaction pairs
- Inclined coordinate system
- Massless ropes and massless, frictionless pulleys
- Coupled objects

Newton's 3rd Law

Common version:

For every action there is an equal and opposite reaction. *

*This is problematic because it suggests that first there is an action and then there is a reaction.

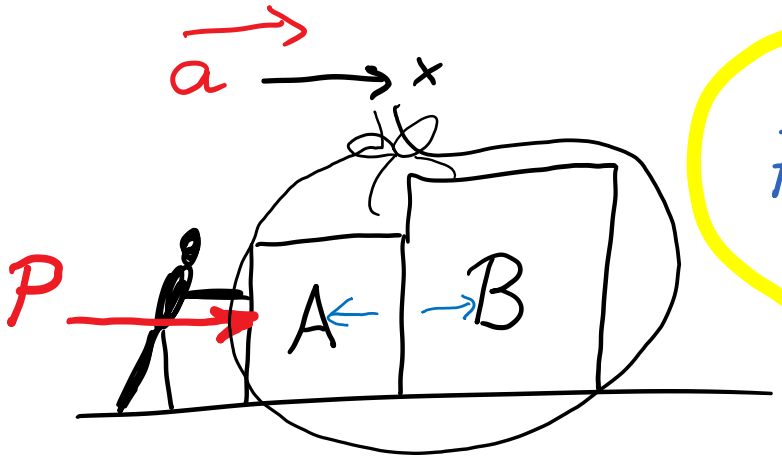
Better version:

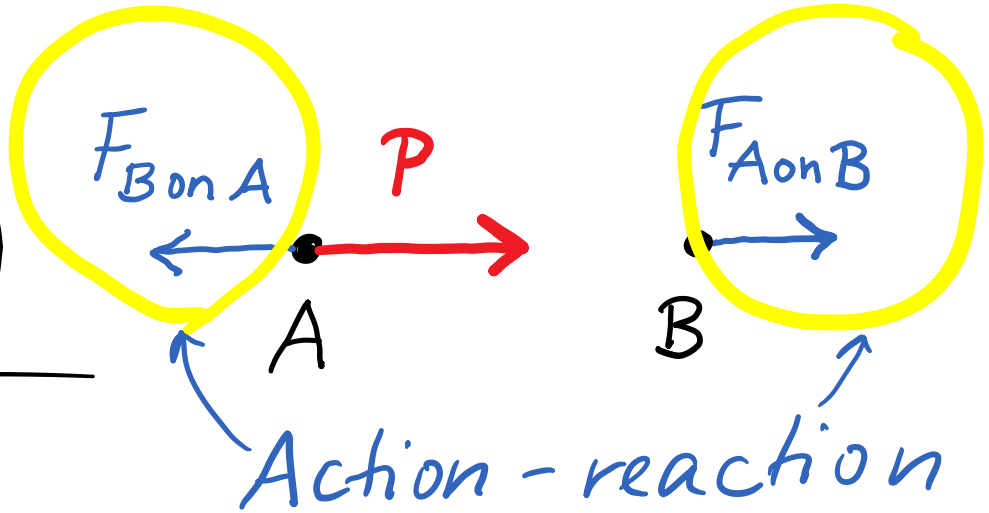
If an object A exerts a force $\vec{F}_{AB}$ on object B, then object B exerts a force $\vec{F}_{BA}$ on object A, with

$$\vec{F}_{BA} = -\vec{F}_{AB}$$

equal in magnitude, opposite in direction.

Action-reaction pairs





$$\vec{F}_{A\,on\,B} = -\vec{F}_{B\,on\,A}$$

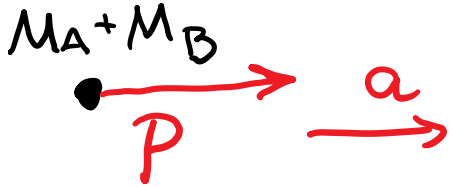
$$\Sigma F_x = M_A a_x$$

$$P - F_{B\,on\,A} = M_A a_x$$

$$\Sigma F_x = M_B a_x$$

$$F_{A\,on\,B} = M_B a_x$$

$$P = (M_A + M_B) a_x$$

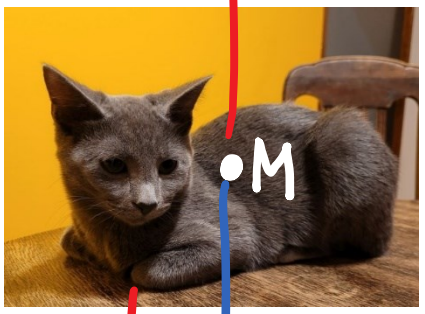


Example: Cat at Rest on a Table

$\vec{N} = -\vec{W}$
because $\vec{a} = 0$ (Newton's 2nd law)

But $\vec{N}$ and $\vec{W}$ are not an action-reaction pair!

Action-reaction pairs are:
{$\vec{W}$ and $\vec{F}_{grav\ Earth\ by\ M}$}
and
{$\vec{N}$ and $\vec{F}_{table\ by\ M}$}



N = $F_{M\ by\ table}$

$F_{table\ by\ M}$

W = $F_{Grav\ M\ by\ Earth}$

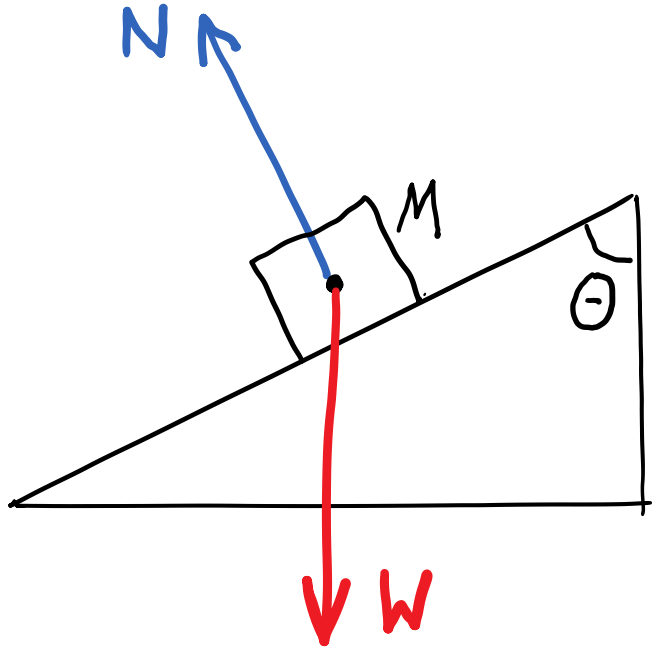
$F_{Grav\ Earth\ by\ M}$

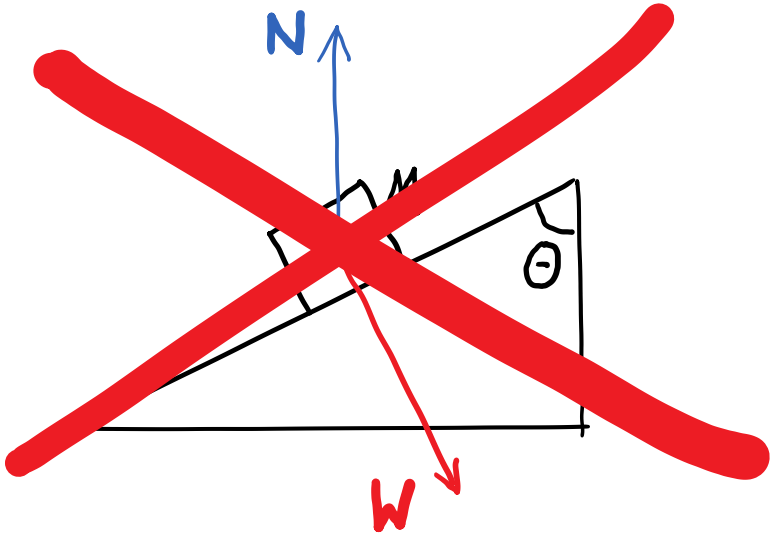
Forces of action-reaction pair act on two different objects

Object on inclined plane

Normal = perpendicular
Normal force must be perpendicular to surface

Weight: vertically down

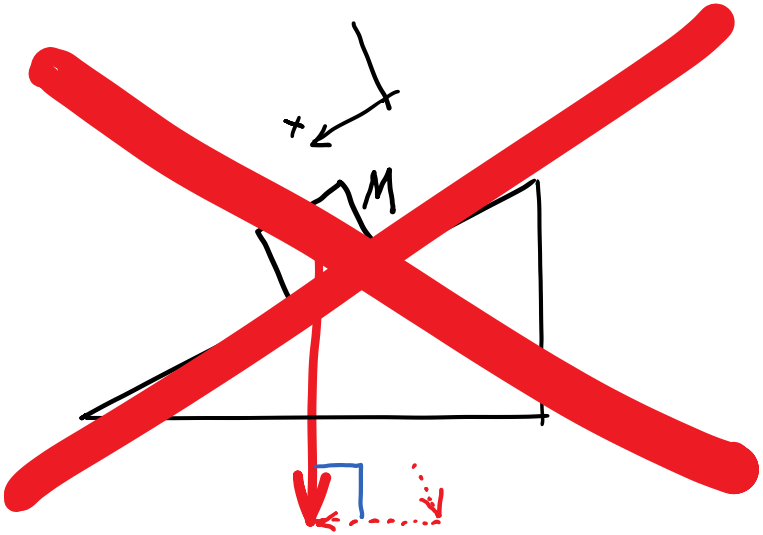


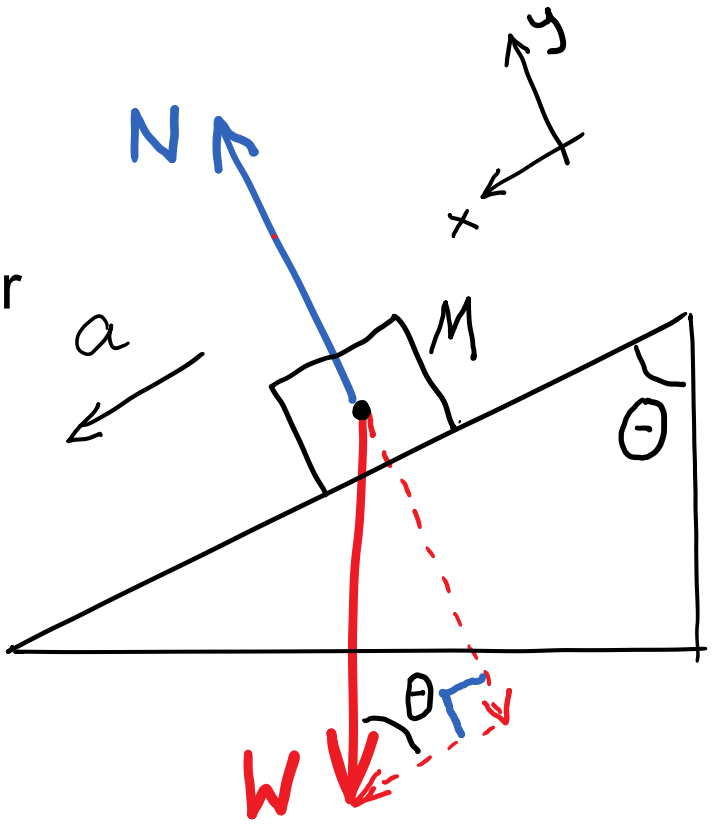


Object on inclined plane

Choose axis in direction of acceleration.

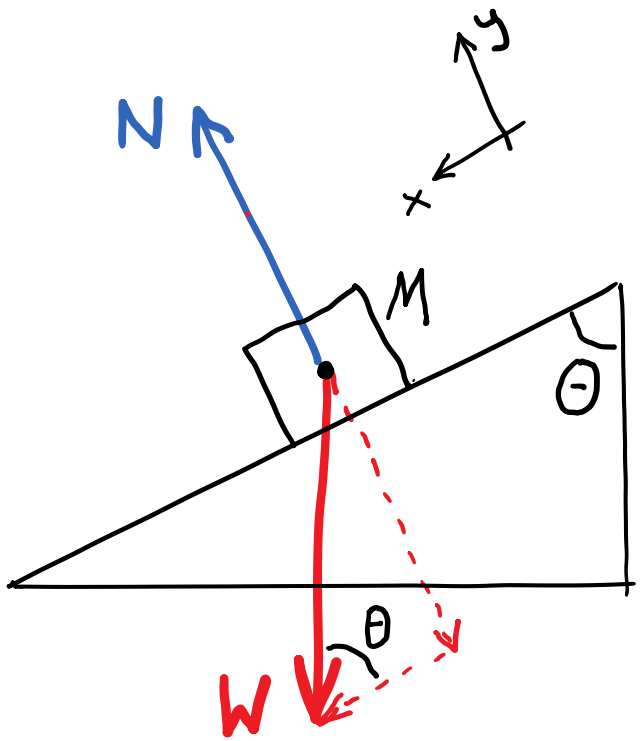
Draw components of weight vector





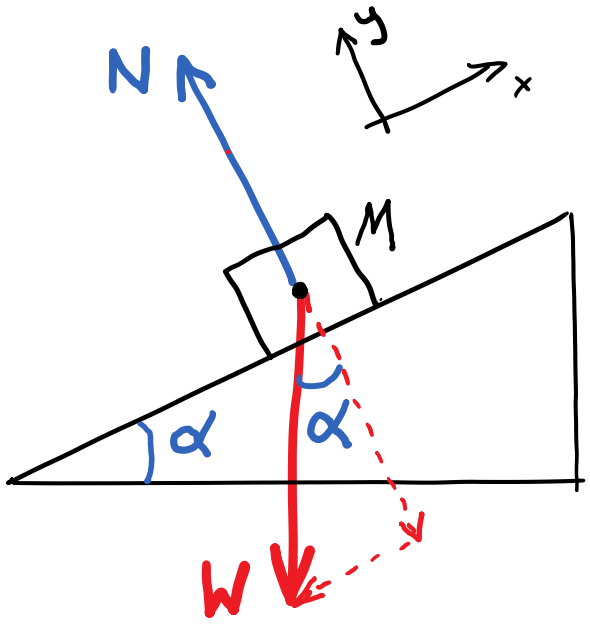
Identify θ in the weight triangle

Components of weight vector



In this coordinate system:

$$W_x = +W\cos\theta = +Mg\cos\theta$$
$$W_y = -W\sin\theta = -Mg\sin\theta$$

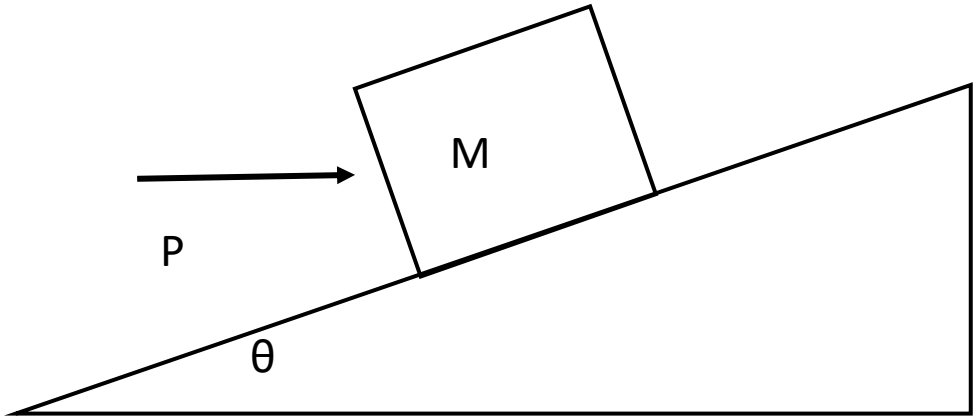


CAUTION: Do not memorize!
If α were angle with horizontal and if x-axis had opposite direction:

$$W_x = -W\,sin\,\alpha = -\,Mg\sin\alpha$$
$$W_y = -W\cos\alpha = -Mg\cos\alpha$$

Example: object on incline

A crate of mass *M* is pushed up a frictionless inclined ramp that makes an angle θ with the horizontal by means of a horizontal pushing force of constant magnitude *P.*
Find the acceleration of the crate.



Coupled objects: ropes and pulleys

We make the following approximations:

- massless, un-stretchable rope

→ tension is constant throughout the rope

- massless, frictionless pulley

→ tension remains constant as rope passes over pulley

Caution:

If mass and spatial extension of the pulley are taken into account, the tension does not remain constant! We will study this with Rotational Motion in lectures 18-21.

Example with coupled objects

Two blocks are connected by a massless string. A block of mass *m* is on a frictionless inclined plane that makes angle *θ* with the ***vertical***, while a block of mass *M* hangs over a massless and frictionless pulley.
Derive an expression for the acceleration of the blocks in terms of relevant system parameters.