Lecture 2

Newton’s first and second laws

Newtons First Law
or Law of Inertia

If no net external force is applied to an object, its velocity will remain constant ("inert").

OR

A body cannot change its state of motion without outside influence.

What if there is a net force?

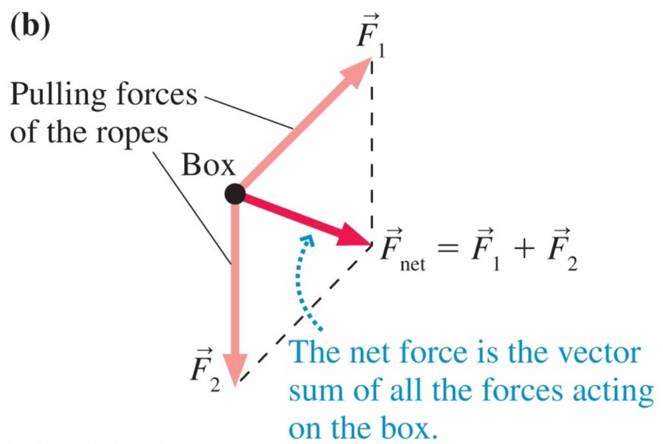
KJF §4.1

Free-body diagrams

Definition: A diagram showing all the forces acting on a body.

1) Draw a dot to represent the body
2) Draw each force acting on the body as an arrow originating at the dot
3) Draw the net force vector

e.g. the forces on the box in the previous example.



KJF §4.7

Kinds of forces

The most important forces we will deal with are

- Weight
- Normal force
- Tension
- Push or pull
- Friction

KJF §4.3

Forces: Weight and Mass

Weight is a force,

∴ the S.I. unit of weight is newtons (N).

Weight is the force exerted on a body by gravity.

Weight is a vector.

What is **mass**?

Mass is the "quantity of matter" in a body, "how much stuff".

The S.I. unit of mass is kilograms (kg).

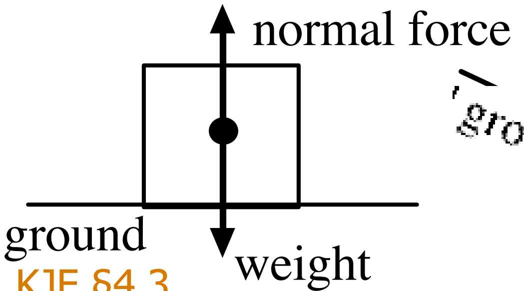
Mass is a scalar.

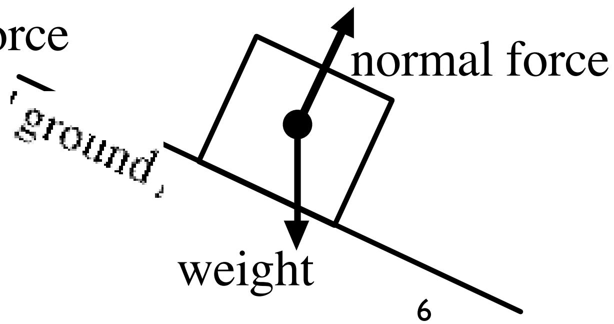
KJF §4.3, see also §5.3

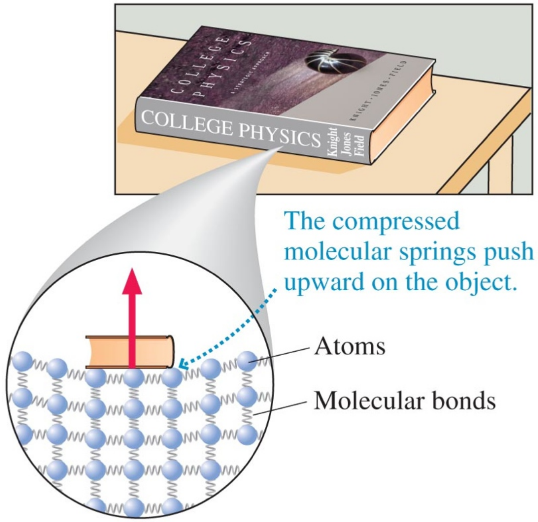
Forces: Normal force

If one pushes against a planar surface, the planar surface pushes back with a force perpendicular ("normal") to that surface.

Normal force always adjusts itself exactly to cancel motion through the surface (unless surface breaks!)







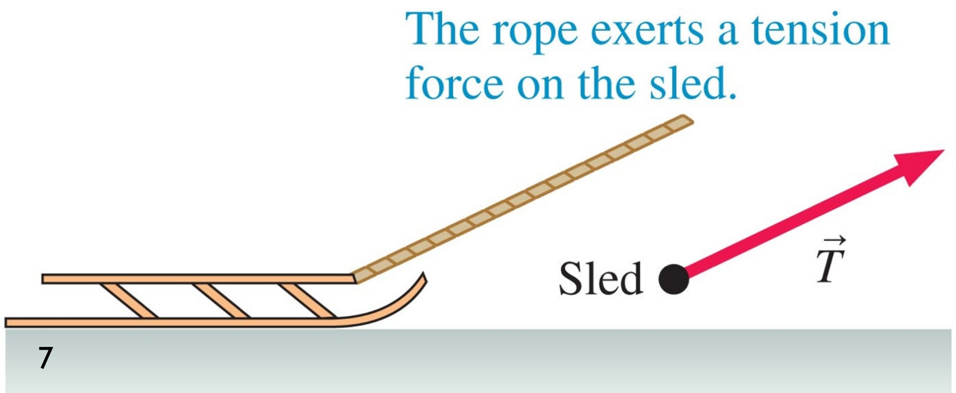
KJF §4.3

Forces: Tension

If a string of negligible mass and stiffness ("ideal string") is pulled tight, both ends of the string pull back with a force called tension.

Tension always pulls inwards along the direction of the string.

The forces at both ends of the string are always the same magnitude. The tension is the same all the way along the string.

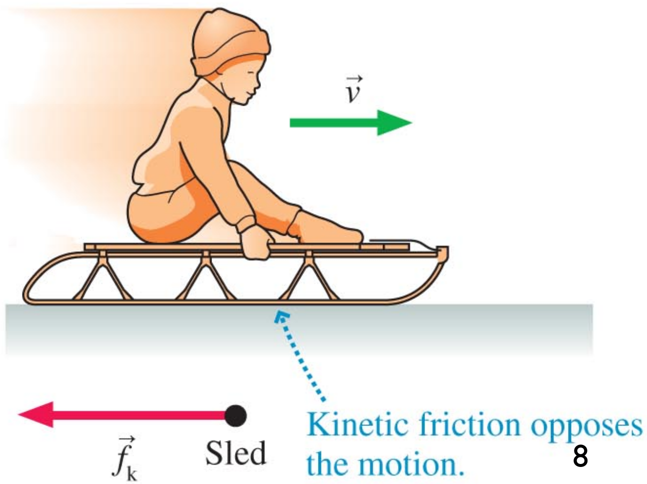


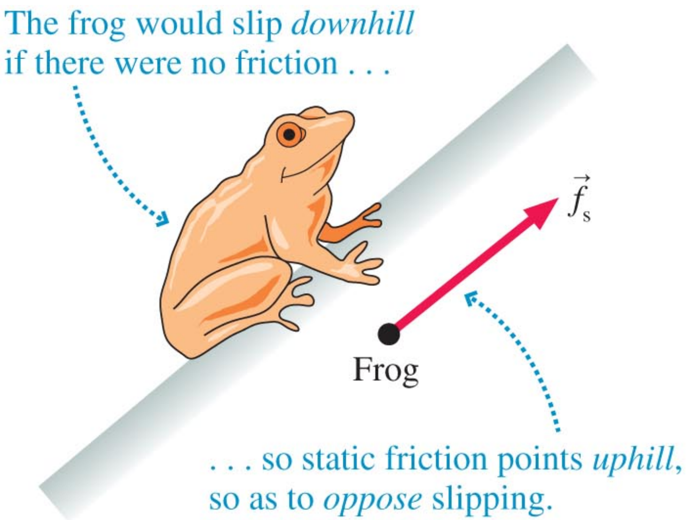
KJF §4.3

Forces: Friction

Friction is a force exerted by a surface. It is always parallel to the surface, and always opposes the direction of motion of slippage of the surface making contact.

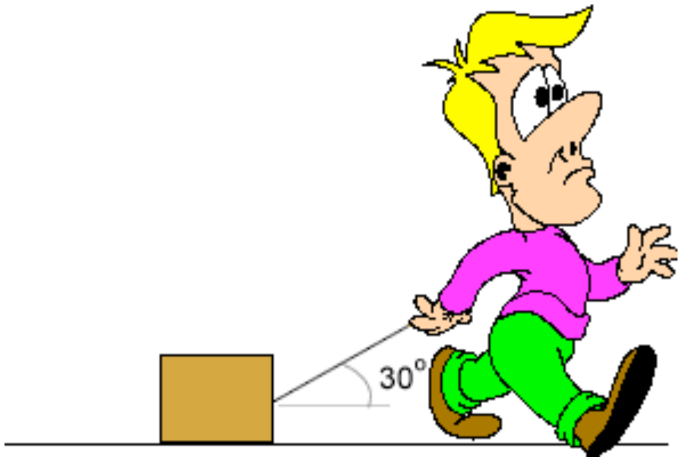
We will look at friction in more detail in Lecture 4.

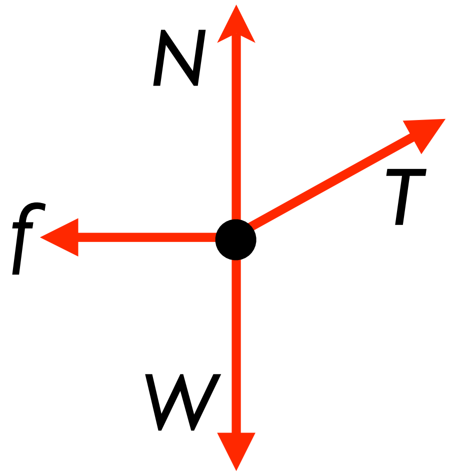




KJF §4.3

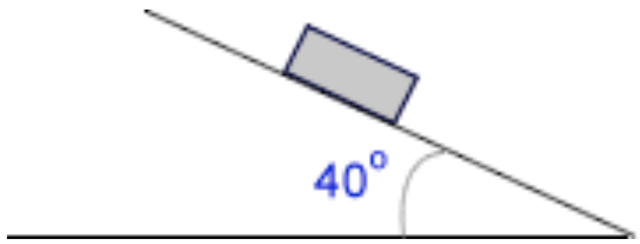
Free body diagrams: Example 1

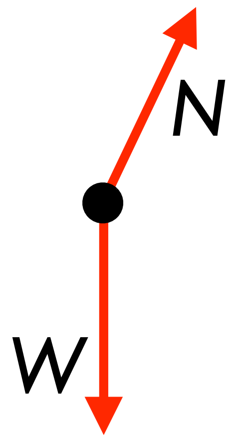




Example 2

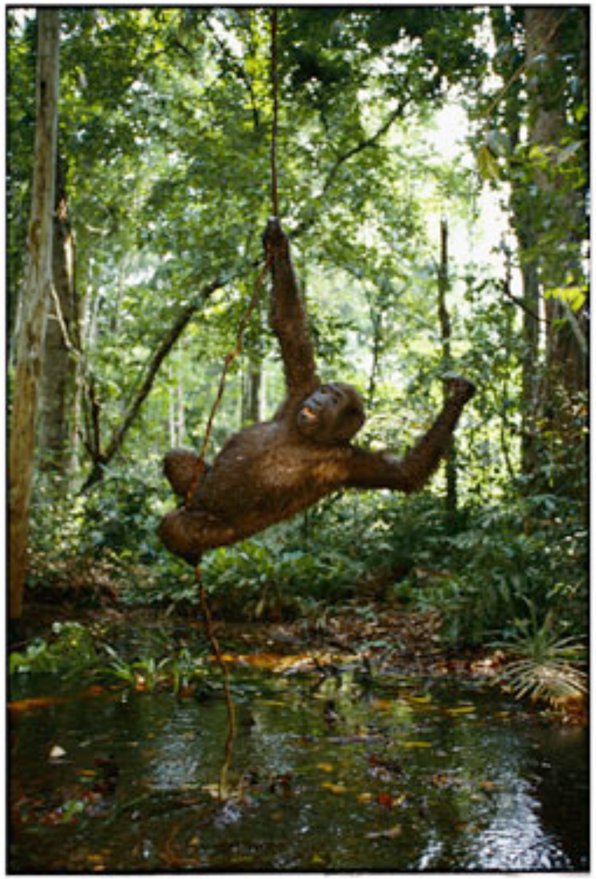
Block sliding down a smooth slope

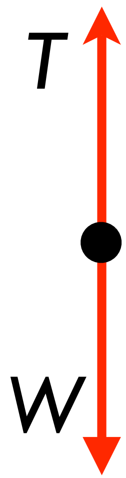




Example 3

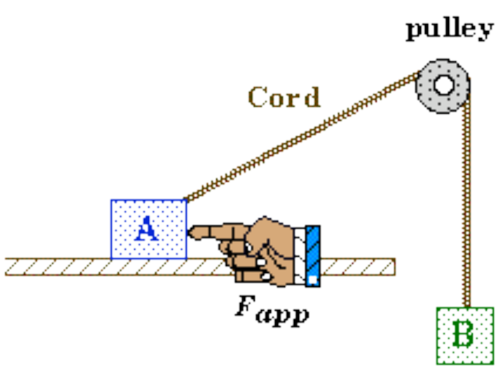
Gorilla swinging on a vine



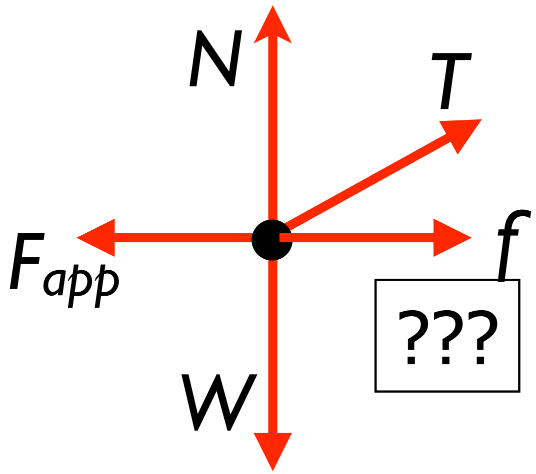


Example 4

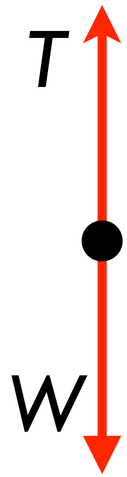
Pushing a block attached to a pulley



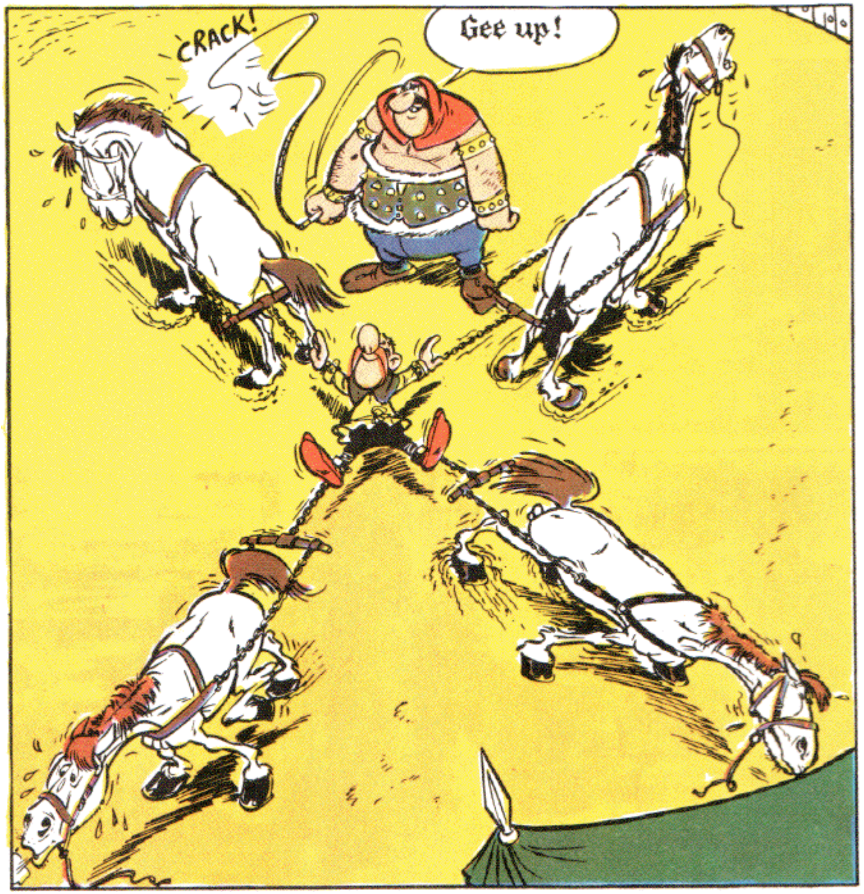
block A:

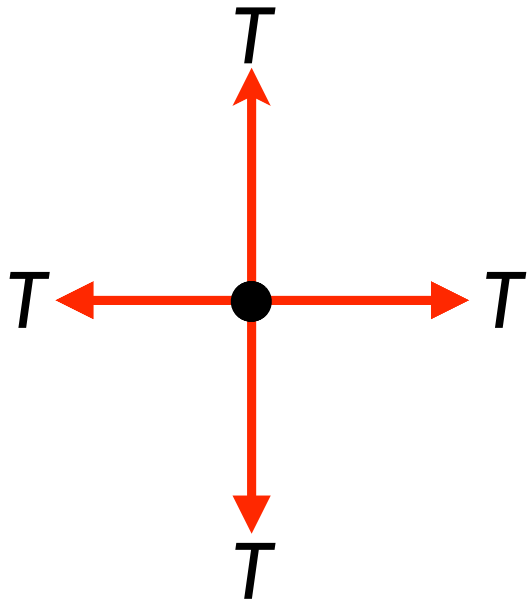


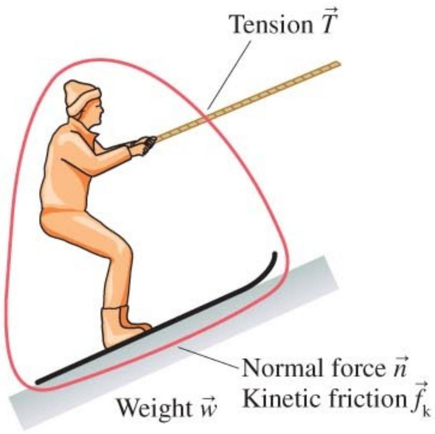
block B:

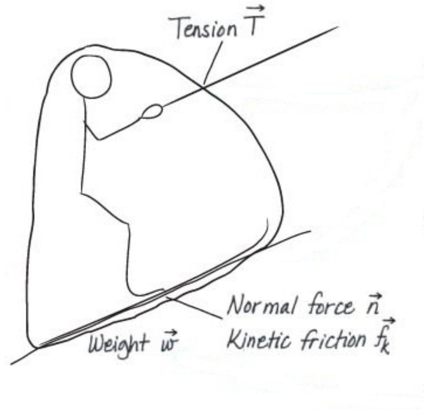


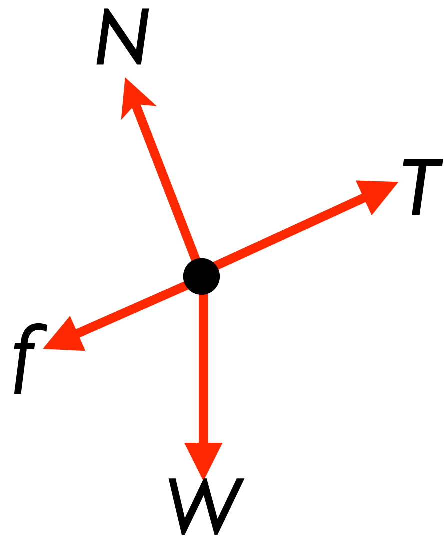
Example 5











1. Identify system
2. Identify contact forces and long-range forces
3. Draw a FBD

Only forces are shown on free-body diagrams (not velocities etc.)

Force and Acceleration

- Can show experimentally that $\underline{a} \propto \underline{F}$

  (for constant m)

- Can show experimentally that $|\underline{a}| \propto 1/m$

  (for constant $\underline{F}$)

  Thus we have

$$\underline{a} \propto \underline{F}/m$$

  OR in other words…

KJF §4.5

Newton's Second Law

$$\underline{F}_{net} = m\underline{a}$$

where $\underline{F}_{net}$ is the resultant or "net" force on a body (N), m is its mass (kg), and $\underline{a}$ is acceleration (ms^{-2}).

Consequences:

- If sum of all forces on a body does not add to zero, then acceleration occurs; and
- If a body is accelerating, there must be a force on it.

KJF §4.6

Newton's Second Law (2)

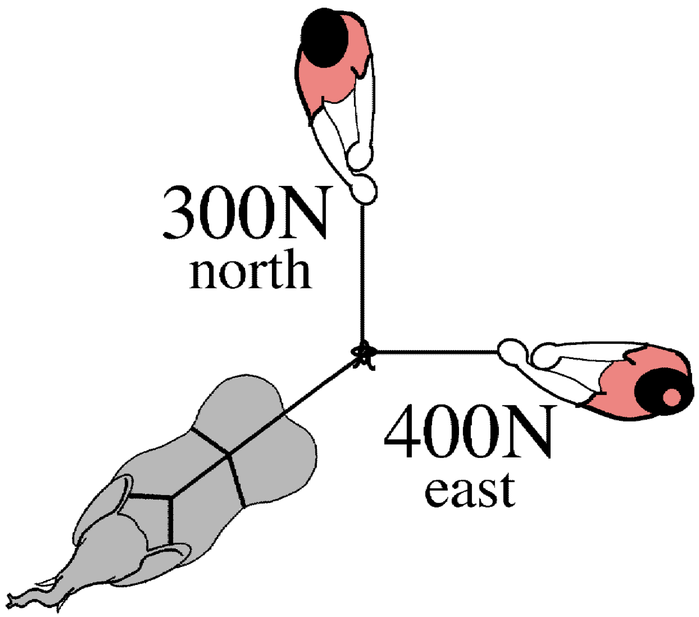
Remember:

- Can also write $\sum \underline{F} = m\underline{a}$ to remind us to use net force
- Only the forces ON a particular body ("the system") are combined to find $\underline{F}_{net}$
- Acceleration always same direction as net force.
- You can separate the components of F and a to give the equations $F_x = ma_x$, $F_y = ma_y$, and $F_z = ma_z$ which are now (signed) scalar equations.
- If $\underline{F} = 0$ body is in "equilibrium". Sum of force vectors forms a closed loop.

KJF §4.6

Example

Find tension in (and direction of) the rope attached to the elephant. Everyone is stationary. *(Use 3 sig figs)*



(θ = ***36.9° south of west***)

Weight, again

Weight is the force exerted on a body by gravity

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

Gravity acts vertically so consider only vertical component

$$F_W = F_y = ma_y$$

In free fall, acceleration $g = 9.8\ \text{ms}^{-2}$

$$F_W = mg$$

∴ a person with a mass of 70 kg has a weight

$$W = 70 \times 9.8\ \text{ms}^{-2} = 690\ \text{N}$$

(downwards! Always give vector's direction) 2 sig figs!