Lecture 2

Newton's first and second laws

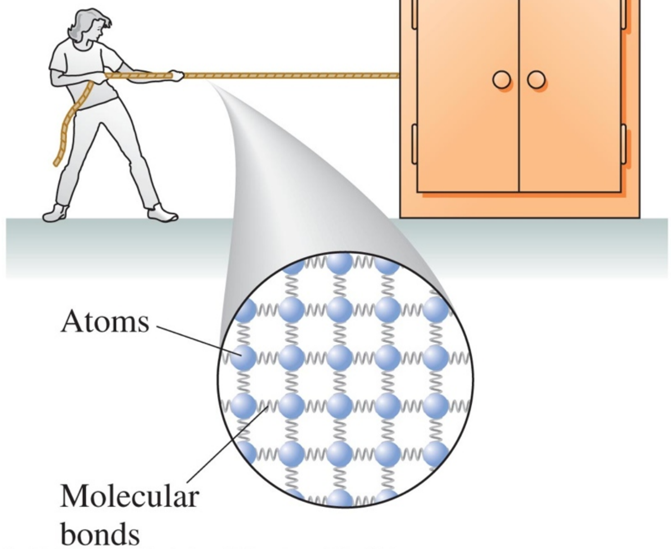
Pre-reading: KJF §4.3 and 4.4

Please log in to Socrative

Recall

Forces are either **contact**

- Pushes / Pulls
- Tension in rope
- Friction
- Normal force



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(virtually all common contact forces are actually electromagnetic)

or **long-range**

- Gravity (Weight)

KJF §4.3

Newtons First Law
or Law of Inertia

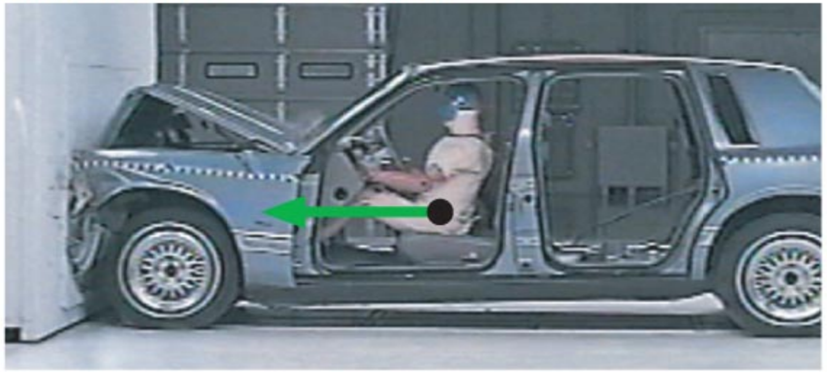
If no net external force is applied to an object, its velocity will remain constant ("inert").

OR

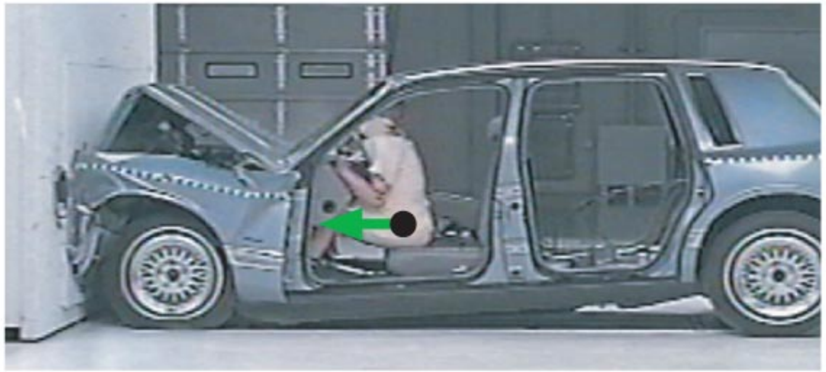
A body cannot change its state of motion without outside influence.

At the instant of impact, the car and driver are moving at the same speed;

The car slows as it hits, but the driver continues at the same speed . . .



. . . until he hits the now-stationary dashboard. Ouch!



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Remember:

- Both magnitude /$\underline{v}$/ and direction are constant!
- An object “at rest” $\underline{v} = 0$, will remain at rest
- Applies if resultant force = 0 ("net" means resultant)

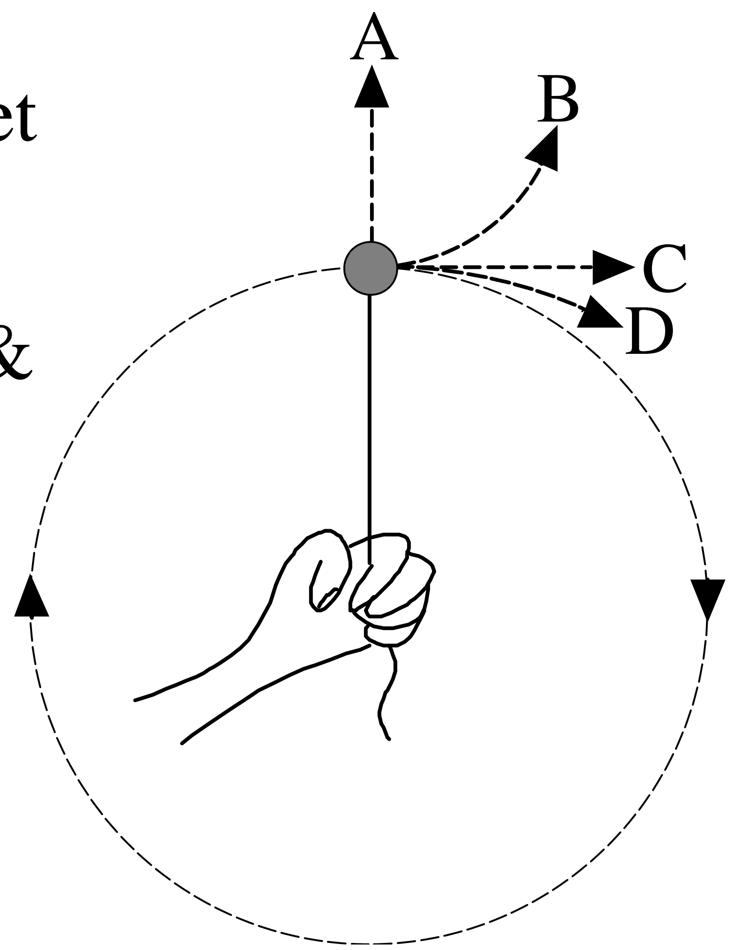
Example

A hockey puck on a string, being rotated rapidly on a horizontal sheet of ice

(i.e. we can ignore vertical forces & friction)

Let go of string.

Which way does it go?



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

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

Calculating the net force

There can be many separate forces acting on a body, but only one acceleration. N2L tells us that the acceleration is proportional to $\underline{F}_{net}$, the net force

$\underline{F}_{net}$ is the vector sum of all the forces acting:

$$\underline{F}_{net} = \underline{F}_1 + \underline{F}_2 + \underline{F}_3 + \ldots$$

To calculate $\underline{F}_{net}$, we draw a **free-body diagram**

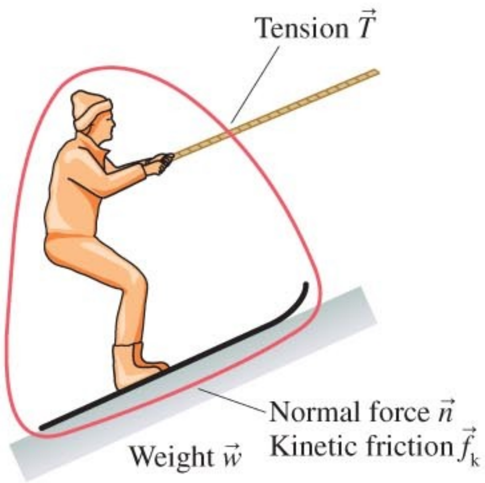
KJF §4.2

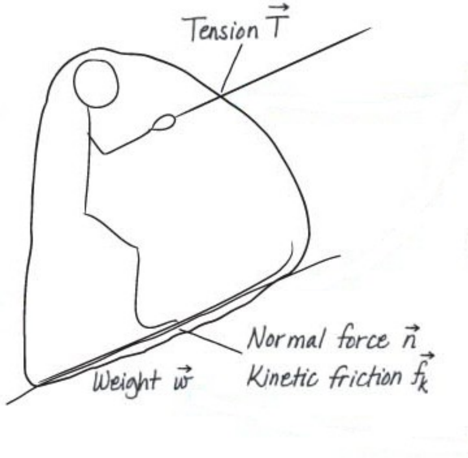
Free-body diagrams

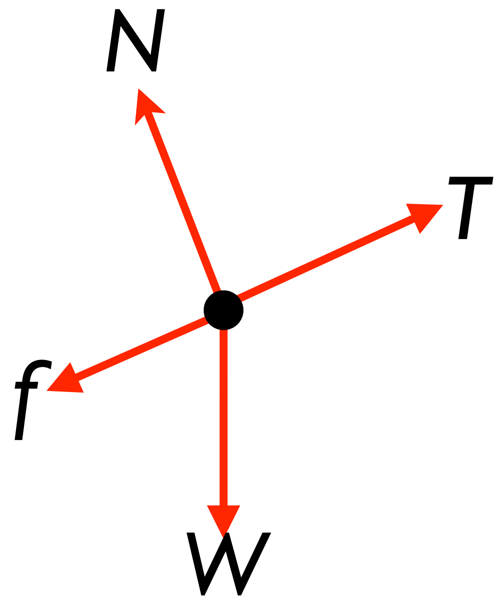
Definition: A diagram showing all the forces acting on a body.

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

KJF §4.7







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.)

Examples

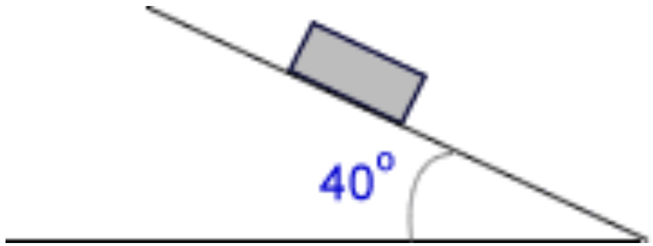
For each example on the sheet, draw a free-body diagram.

1) Draw a dot to represent the body

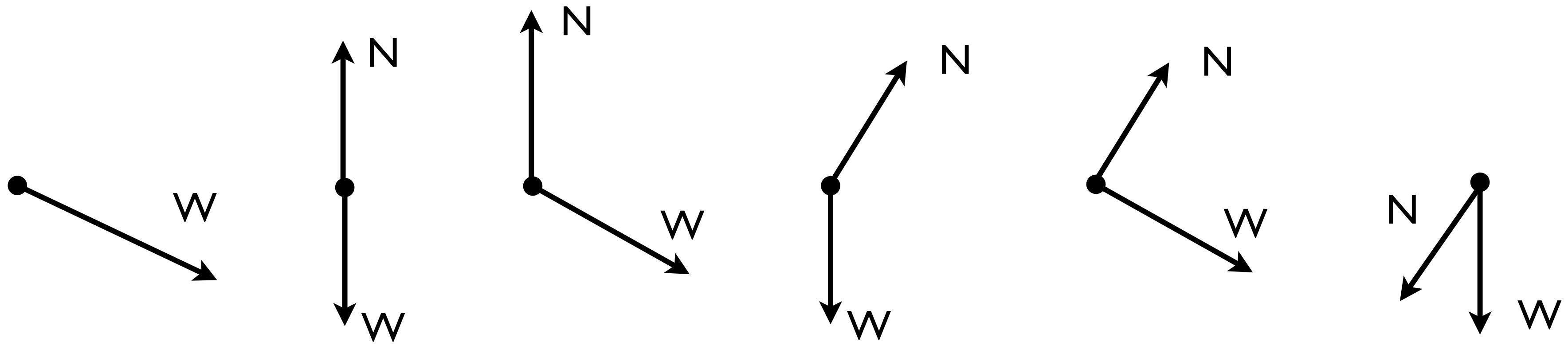
2) Draw each force acting on the body as an arrow originating at the dot

3) Draw the net force vector

FBD problem 1

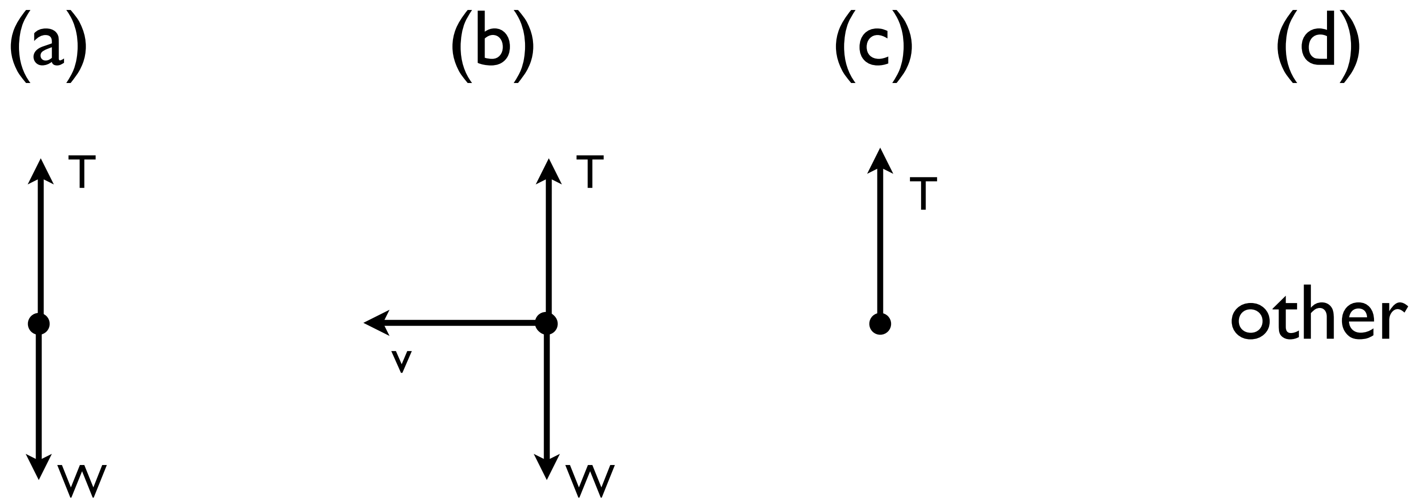


(a) (b) (c) (d) (e) (f)



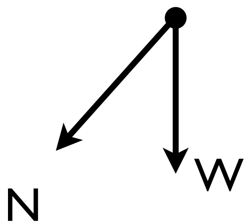
FBD problem 2

Gorilla is swinging to the left.

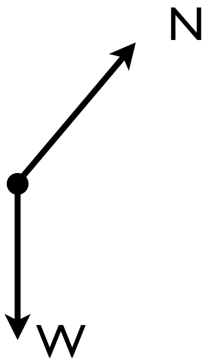


FBD problem 3

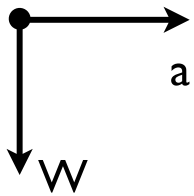
(a)



(b)



(c)



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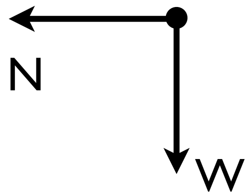
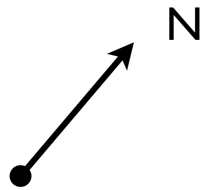
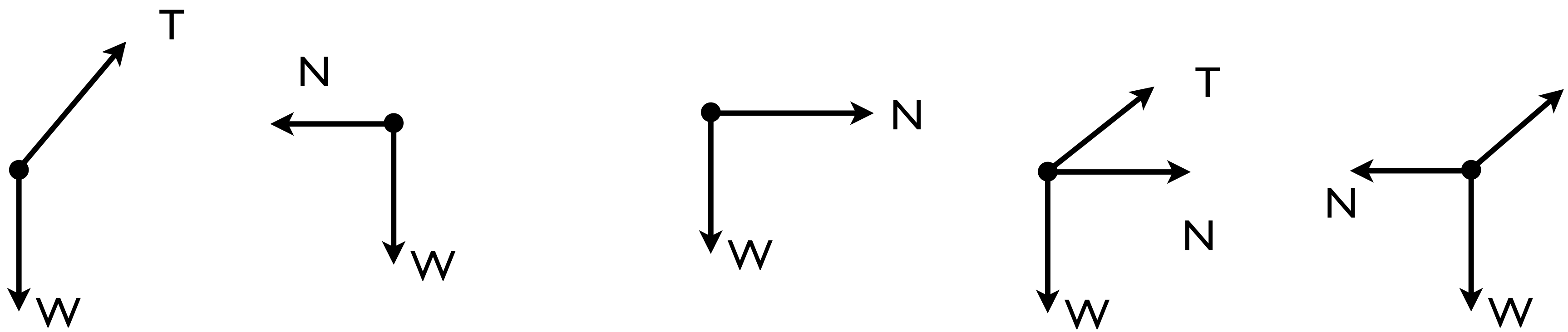


(e)

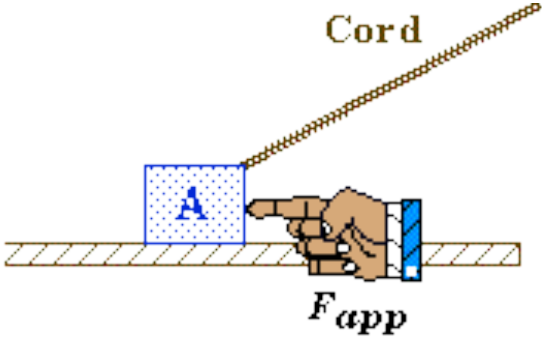


FBD problem 4

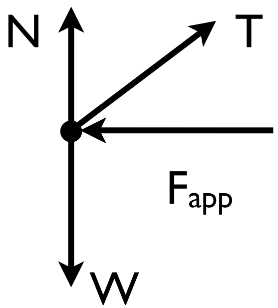
(a) (b) (c) (d) (e)



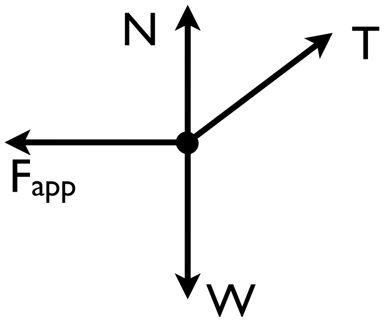
FBD problem 5



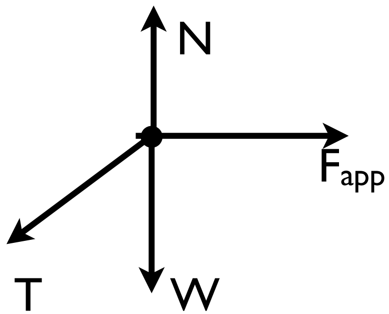
(a)



(b)



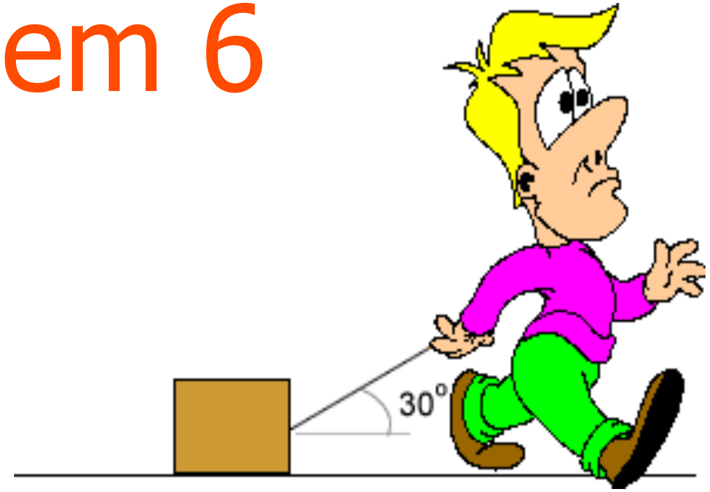
(c)



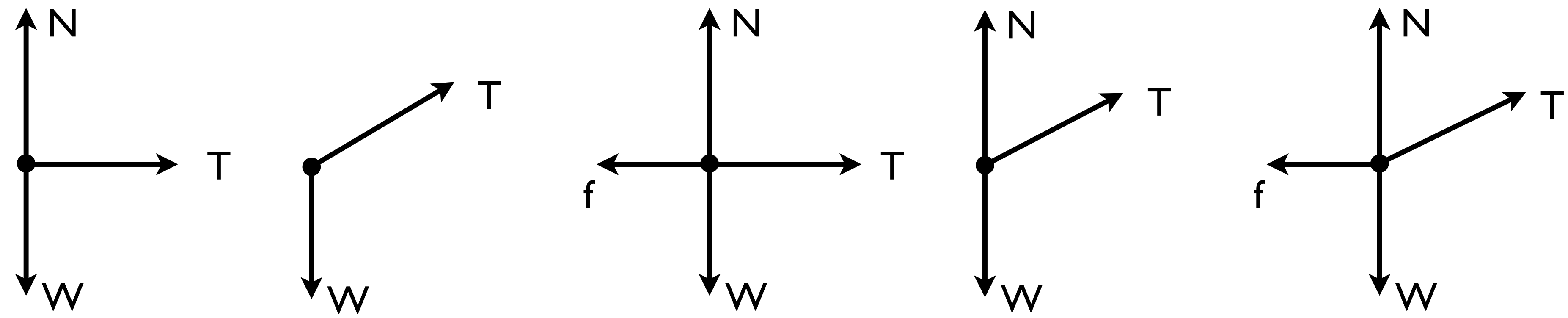
(d)

other

FBD problem 6



(a) (b) (c) (d) (e)



(f) other

Newton's Second Law (2)

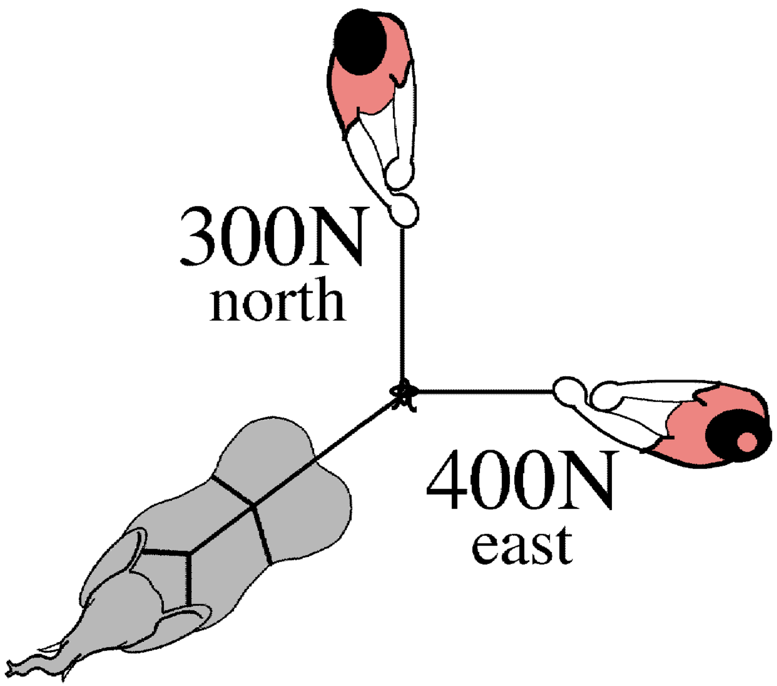
Remember:

- 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 $\underline{F}_{\text{net}}$
- Acceleration always same direction as net force.
- You can separate the components of $\underline{F}$ and $\underline{a}$ 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

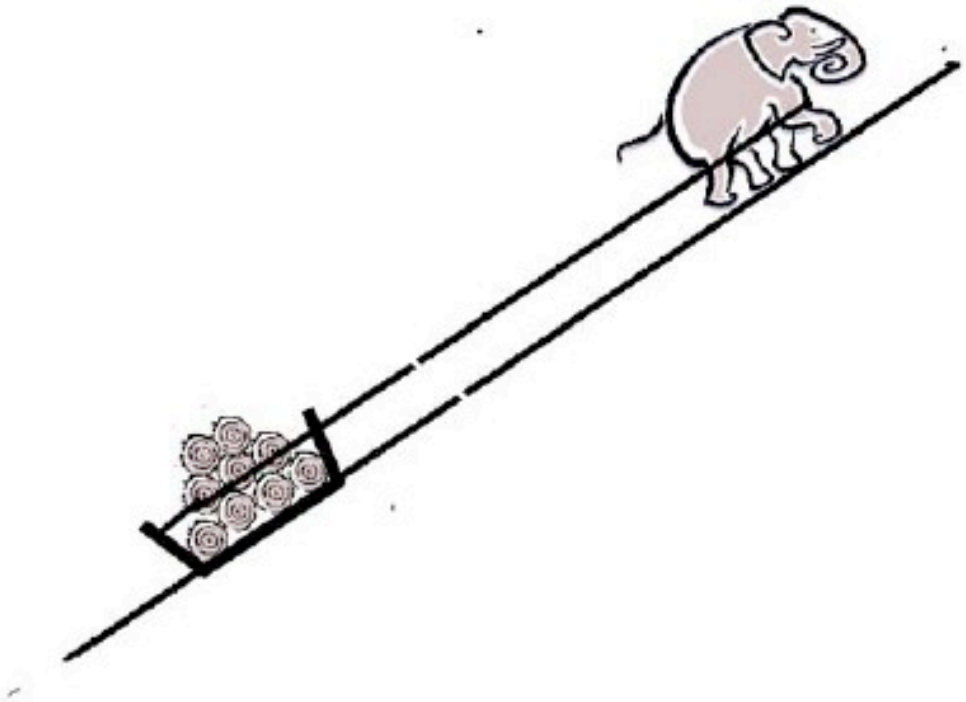
Example

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)

2008 exam Q10

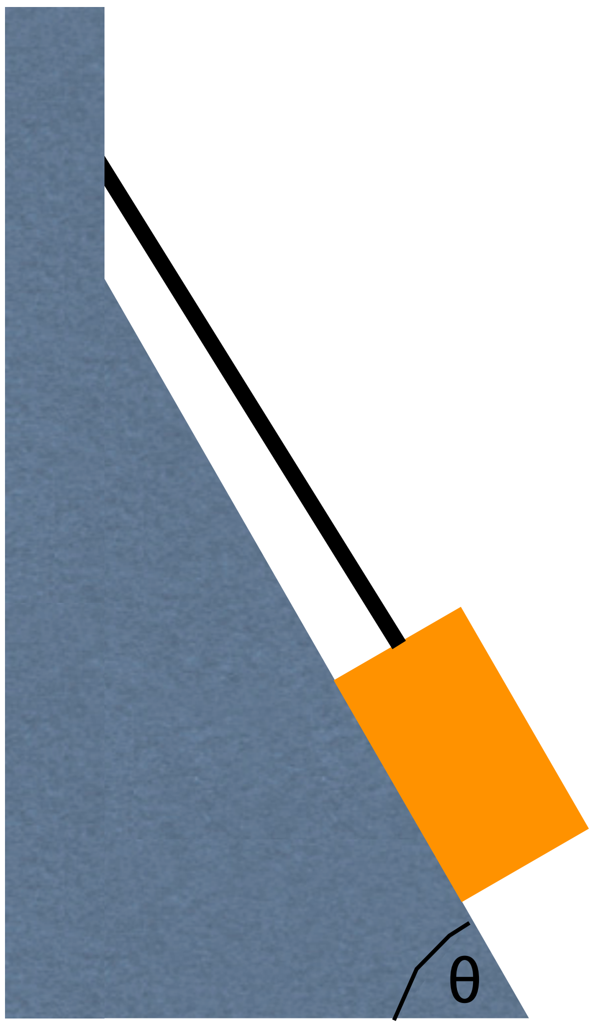


An elephant drags a tray of logs of total weight 10000 N up a uniform slope. The slope is 20 m in length and is inclined at an angle of 30° to the horizontal. The value of the coefficient of kinetic (sliding) friction between the tray of logs and the slope is 0.50. The elephant walks at a constant speed.

(a) Draw a free-body diagram for the tray of logs.

(b) What is the net force on the tray of logs.

Example 2



A box is held in position by a cable along a smooth slope, as shown.

If θ=60° and *m*=50 kg, find the tension in the cable and normal force exerted by the slope.

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 $g = 9.8\ \mathrm{ms}^{-2}$

$$W = mg$$

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

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

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

Example

A woman has a mass of 55.0 kg.

(a) What is her weight on earth?

(b) What are her mass and her weight on the moon, where $g = 1.62\ \mathrm{ms}^{-2}$?

NEXT LECTURE

Interactive Lecture Demonstration (ILD)
on
Newton's first and second laws.