Dynamics

Why and how an object moves?

Newton's Laws

Newton's second law of motion

The acceleration of an object is directly proportional to the net force acting on it and is inversely proportional to its mass. The direction of the acceleration is in the direction of the net force acting on an object

$$a = \Sigma F/m$$

Units of Force

- $F_{net} = ma$ [kg m/s^2 = 1N]

- Pound is a unit of force not mass
- 1 pound = 4.45N

Newton's First Law of Motion

Every body continues in it's state of rest or of uniform speed in a straight line as long as no net force acts on it

- "Law of inertia"; it also defines an inertial Frame.

Q1. Which of the following is NOT an inertial reference frame (where Newton's Laws are invalid)?

1) A train moving at constant velocity 100m/s;
2) A plane cruising at 900km/hr;
3) A plane during taking off;
4) A space shuttle.

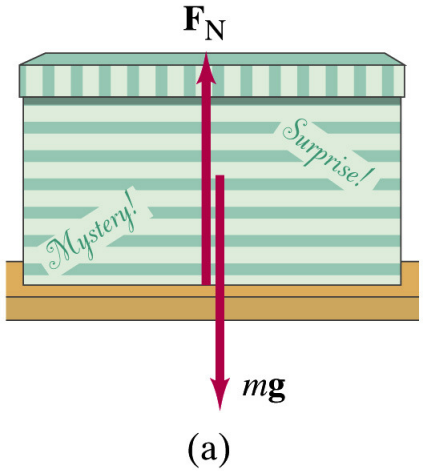
Free Body Diagrams

1) Calculate net forces

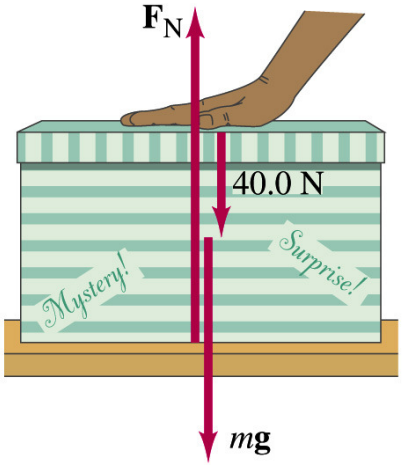
2) Calculate net forces along the direction of motion

- indicate the magnitude of a force by the length of an arrow.

Normal Force



(a)



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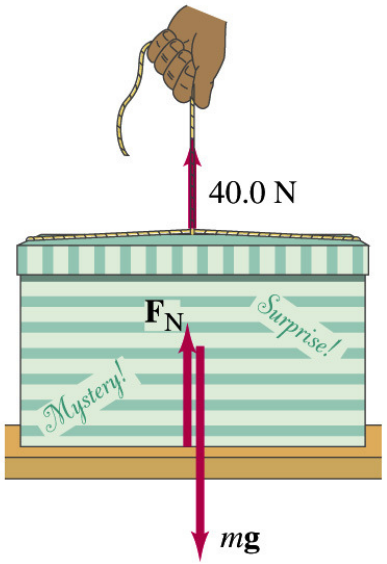

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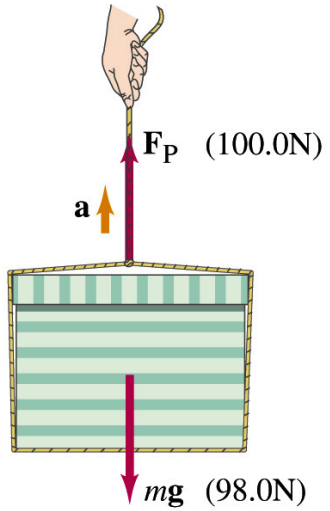
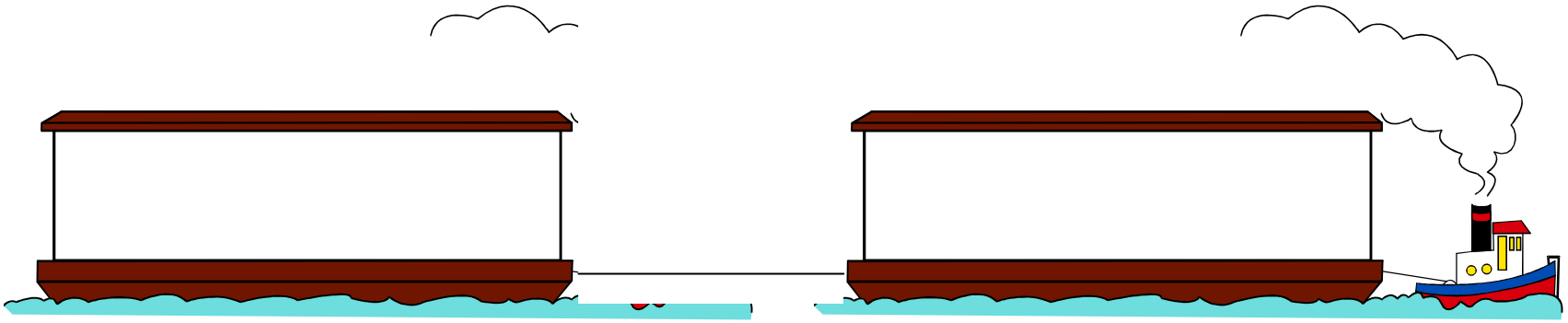


Q2

The weight of the box is 70kg and the pulling force is 900N, the normal force will be about

1) 200N pointing up;
2) 200N pointing down;
3) 1600N pointing down;
4) 0N.

Example 1: A tug with two barges



F_P= 100 000N

m_3 = 100 000

m_2 = 50 000

m_1 = 20 000kg

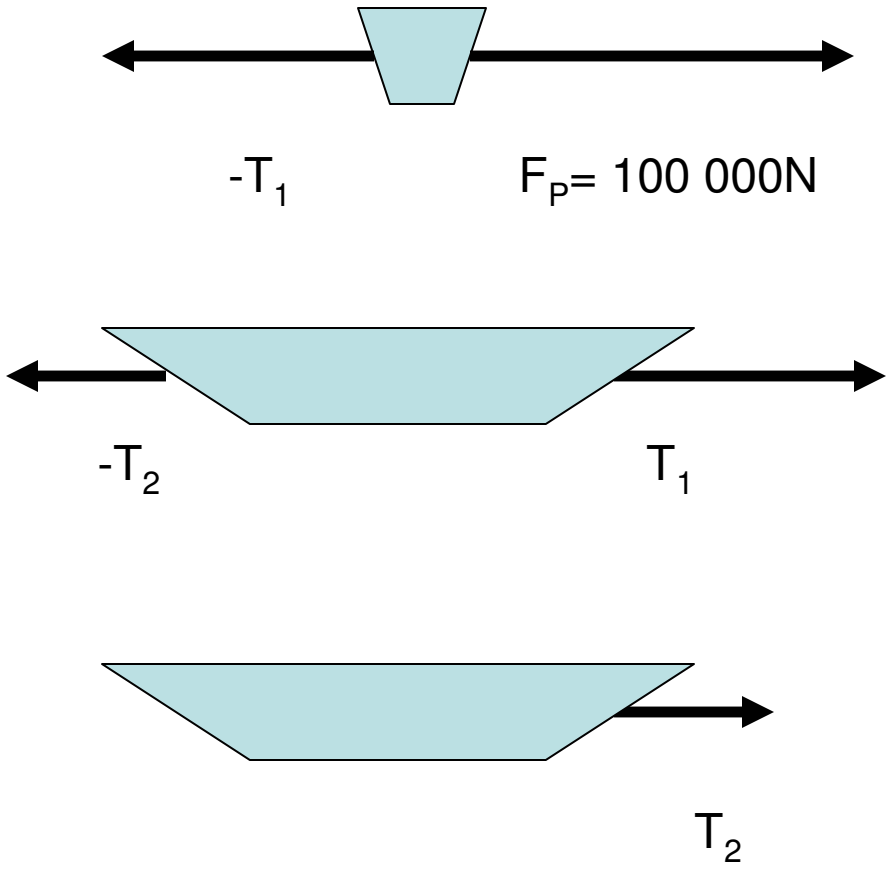
Free body diagrams?

a = ?

T_1 = ? (Tension on the cable between tug and barge 1)

T_2 = ? (Tension on the cable between barges)

Consider the horizontal motion only



- Net force on the tug

$F_P - T_1 = a_x 20\ 000$

- Net force on barge 1

$T_1 - T_2 = a_x 50\ 000$

- Net horizontal force on barge 2

$T_2 = a_x 100\ 000$

All three vessels are moving with the same acceleration a_x

$F_P - T_1 = a_x \cdot 20\,000$

$T_1 - T_2 = a_x \cdot 50\,000$

$T_2 = a_x \cdot 100\,000$

Add these equations together:

$F_P = a_x \cdot 170\,000$

$a_x = 100000\text{N}/170\,000\text{kg} = 0.59\ \text{m/s}^2$

$T_2 = 0.59\ \text{m/s}^2 \cdot 100\,000\text{kg} = 59\,000\text{N}$

$T_1 = T_2 + a_x 50\,000 = 88500\text{N}$

Friction

- Kinetic friction
- Static friction

---Friction force does not depend on the contact area!

- Rolling friction

Coefficients of friction

Static:

$\mu_S = \max(f_s)/n$

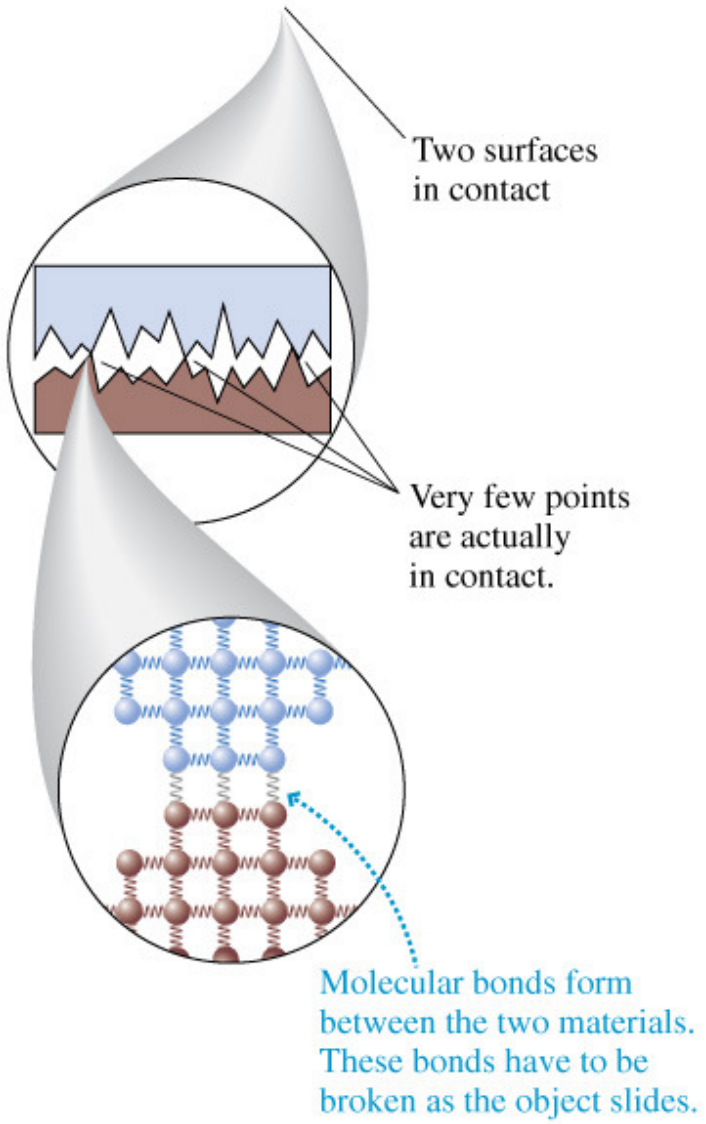
$f_s \leq \mu_S n$

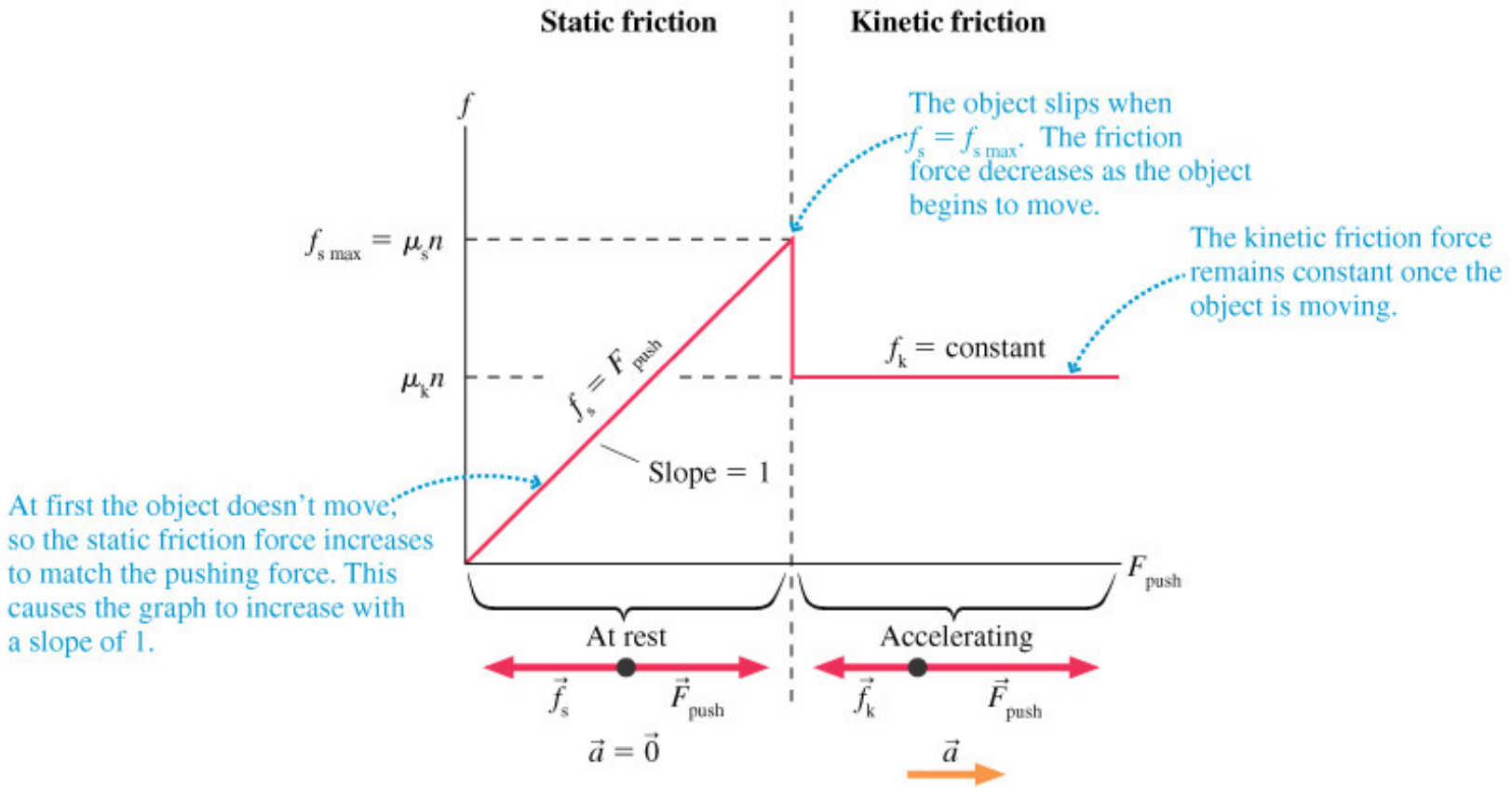
Kinetic:

$\mu_K = f_k/n$

$f_k = \mu_K n,$

$\mu_S > \mu_K$





Drag forcees in gases and liquids

Drag force increases with velocity

$D = c A v^2;$

A is the cross-section area of an object;
v is the velocity.
c is the drag coefficient.
(What is the right SI unit for ‘c’?)

For the air, c=1/4 in SI units.