Automatic Control

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Dynamics

Newton’s Second Law and Units

Equation of Motion

- Newton's Second Law

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

- $\mathbf{F}$ = the **vector sum** of all forces applied
- $\mathbf{a}$ = the **vector** acceleration with respect to an **inertial reference frame**
- m = mass

Units

$$\mathbf{a} = k\frac{\mathbf{F}}{m}$$

"*Acceleration is proportional to force and inversely proportional to mass*"

Have you ever questioned why there is no constant?

English Units

- Constant is not needed if the unit is defined carefully

- SI unit system: create a unit for force → **N** (Newton)
  - The popular unit, **kg**, is a unit of **mass**
  - 1 N: Amount of force that can accelerate a 1 kg object by 1 m/s^2

- English Unit system: create a unit for mass → **slug**
  - The popular unit, **lb**, is a unit of **force**
  - 1 slug: mass of an object that will accelerate by 1 ft/s^2 when 1 lbs of force is applied.

Units

- SI unit system
  - Usually the weight is calculated by multiplying the gravitational acceleration to the mass.

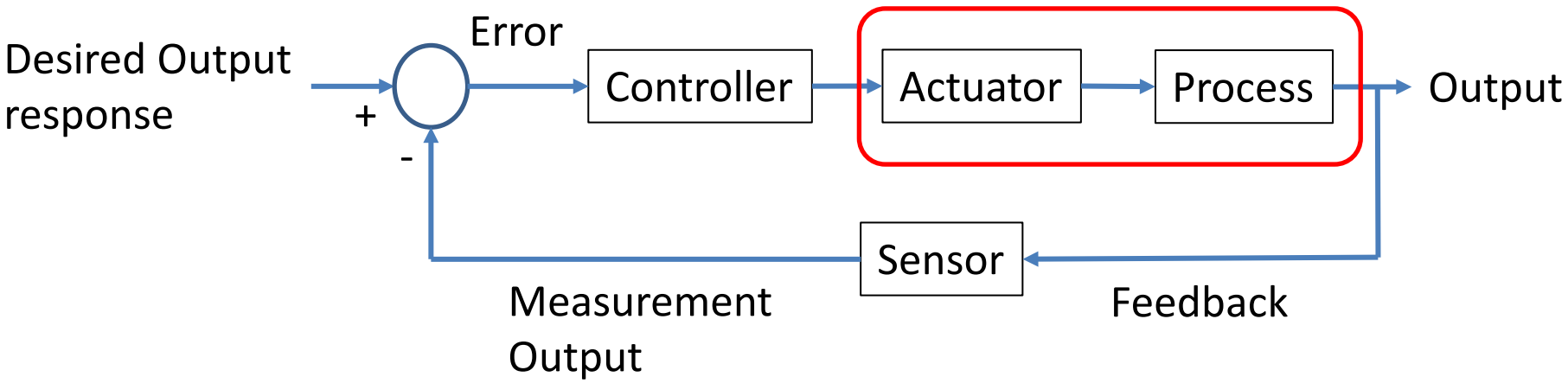
$$1\ \mathrm{N} = 1\ \mathrm{kg} \times 9.8\ \mathrm{m/s^2}$$

- English unit system
  - Usually, the mass is calculated by dividing the weight by the gravitational acceleration.

$$1\ \mathrm{lb} = 1\ \mathrm{slug} \times 32.2\ \mathrm{ft/s^2}$$

$$1\ \mathrm{slug} = 1\ \mathrm{lb}/32.2\ \mathrm{ft/s^2}$$

Importance of Dynamics



Force

- 4 fundamental forces
  - Gravity (중력)
  - Electromagnetic force (전자기력)
  - Weak force (약핵력)
  - Strong force (강핵력)

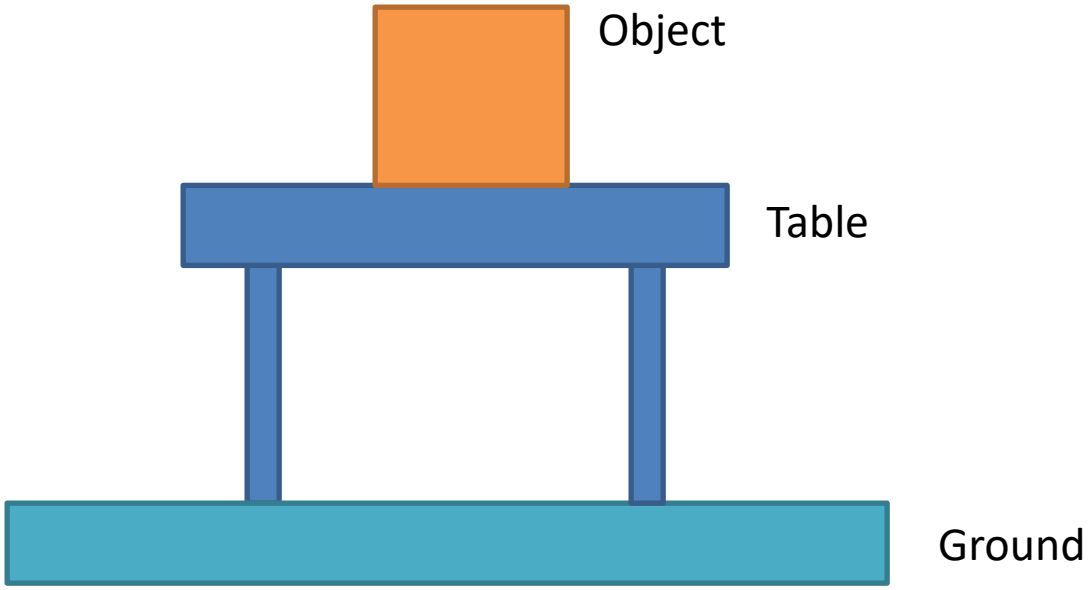
- Then what about these?
  - Normal force
  - Friction
  - Centripetal force
  - Blah blah blah forces

Force

- Fundamental forces
  - ‘body force’
  - ‘without contact’

- Other forces acts by ‘contact’

Free Body Diagram



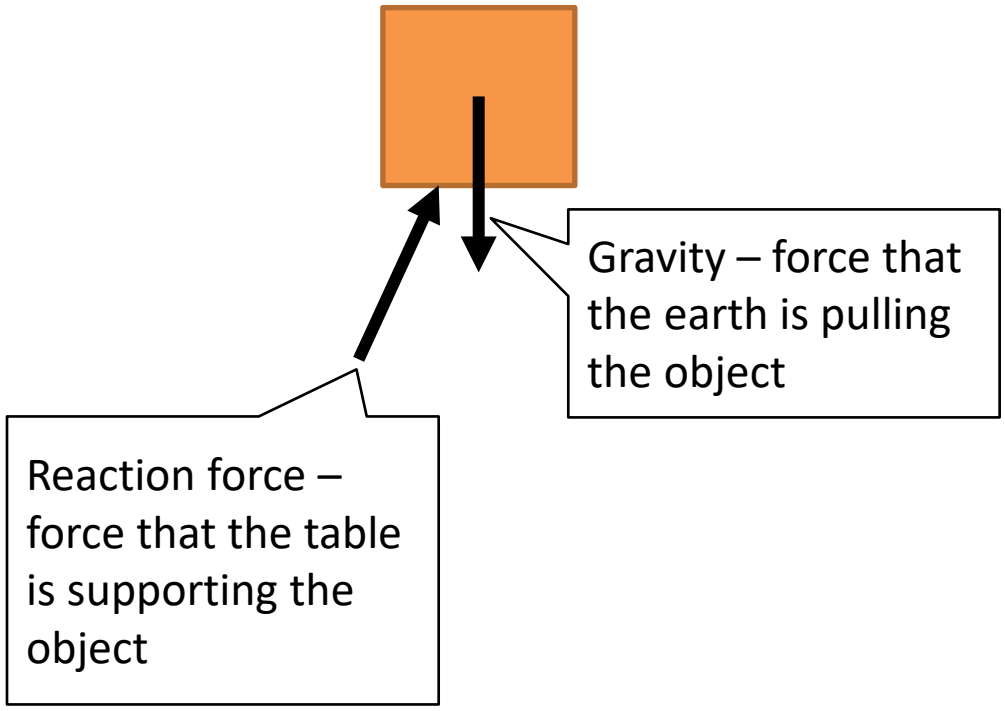
The Object

- Any body force?

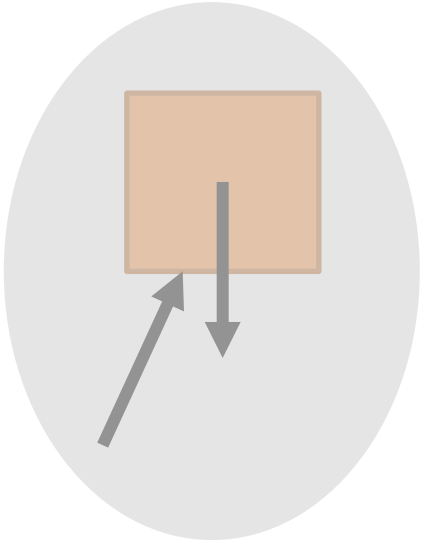
- Any contact?

The Object

- Any body force?
  - Gravity is acting on the object
- Any contact?
  - The object is in contact with the table
  - Then the table will apply force on the object

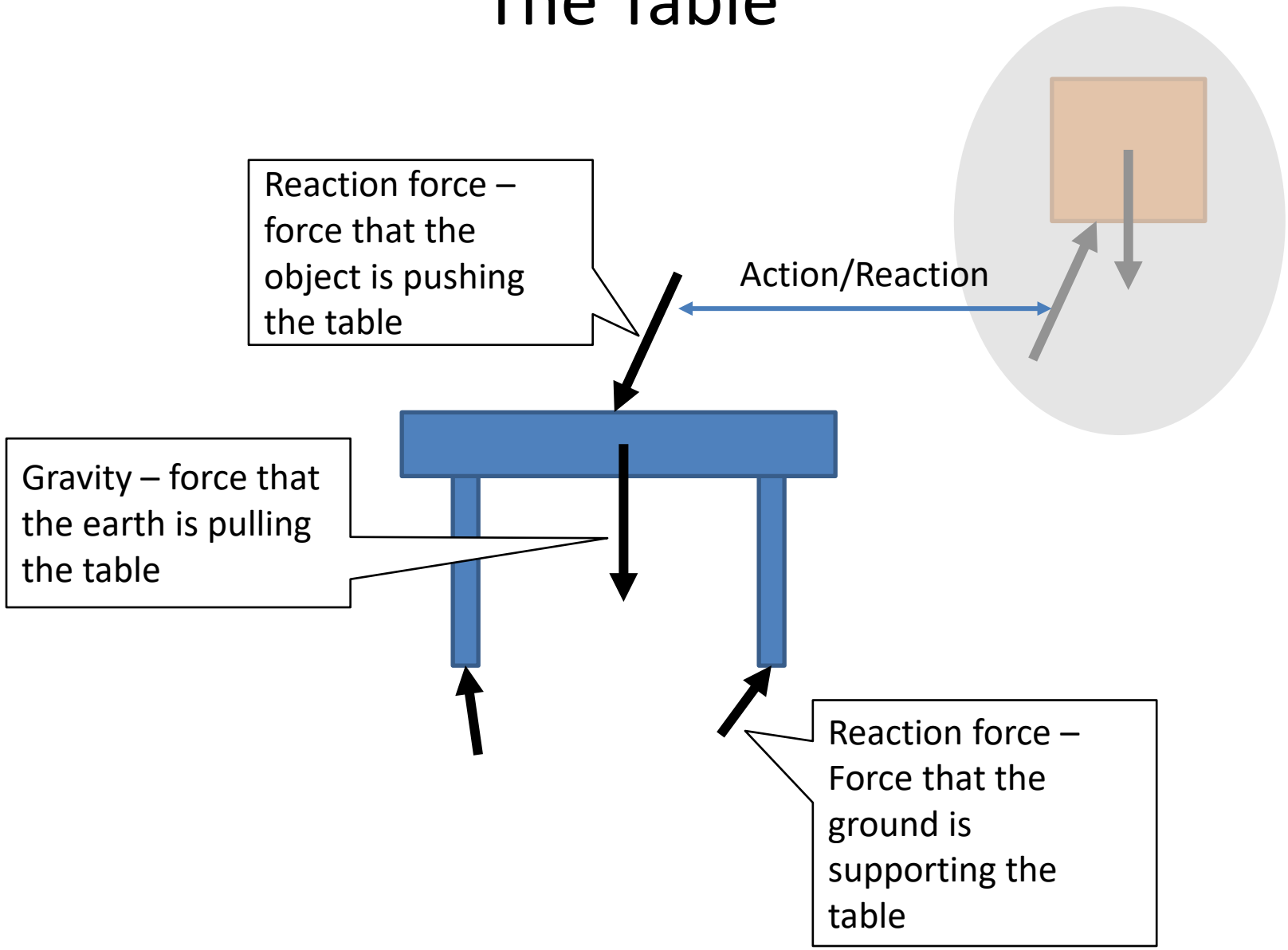


The Table



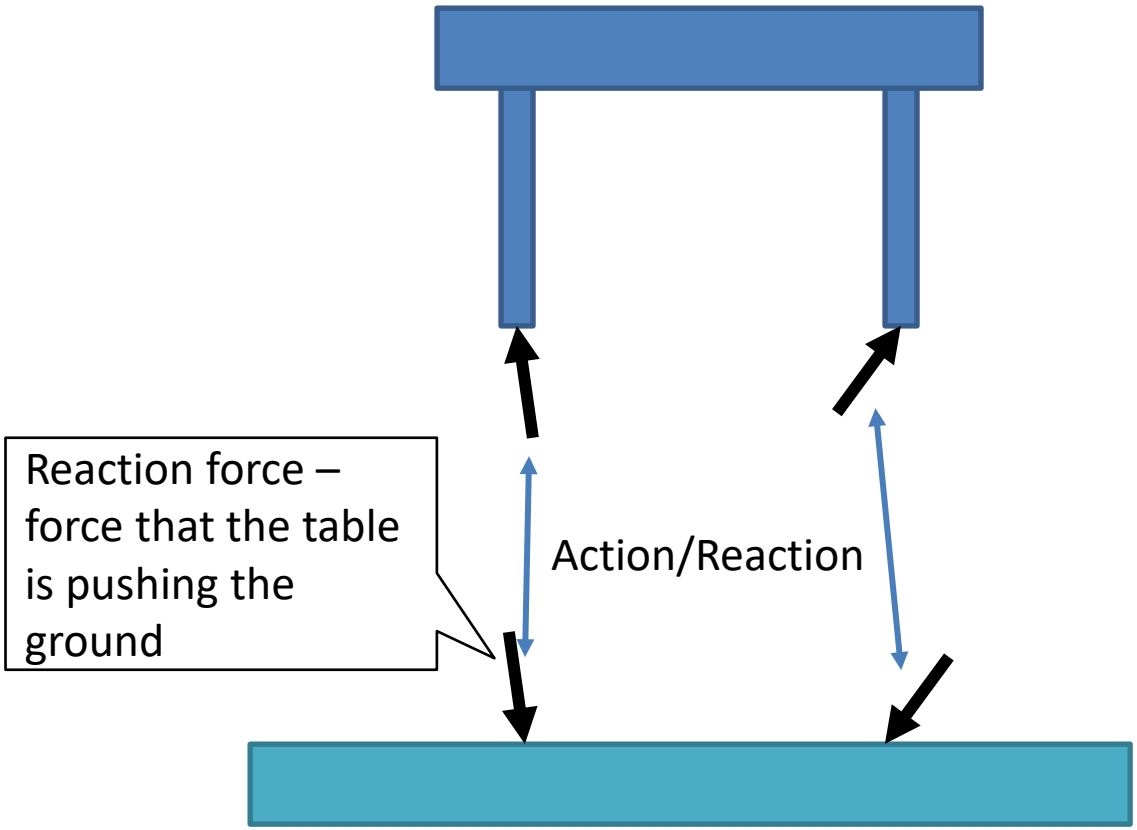
- Any body force?
- Any contact?

The Table


Reaction force – force that the object is pushing the table
Action/Reaction
Gravity – force that the earth is pulling the table
Reaction force – Force that the ground is supporting the table

The Ground (Earth)

The Ground (Earth)



Action/Reaction

- Newton's Third Law
- Regardless of body force or contact force
- Same magnitude and opposite direction
- Assignment of action and reaction is arbitrary

Identification of Action/Reaction

- Object
  - Gravity
    - Action: force that the earth is pulling the object
    - Reaction: force that the object is pulling the earth
  - Force between the object and the table
    - Action: force that the table is supporting the object
    - Reaction: force that the object is pushing down the table

Identification of Action/Reaction

- Table
  - Gravity
    - Action: force that the earth is pulling the table
    - Reaction: force that the table is pulling the earth
  - Force between the object and the table
    - Action: force that the object is pushing down the table
    - Reaction: force that the table is supporting the object
  - Force between the ground and the table
    - Action: force that the ground is supporting the table
    - Reaction: force that the table is pushing down the ground