CENTER OF GRAVITY

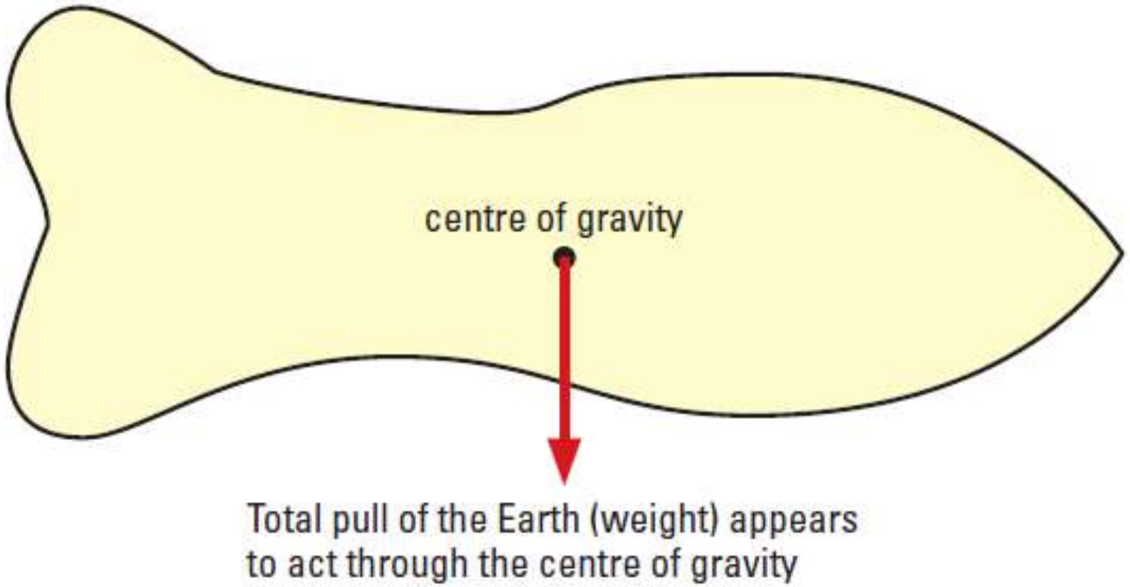
and how it relates to stability

LEARNING OUTCOMES

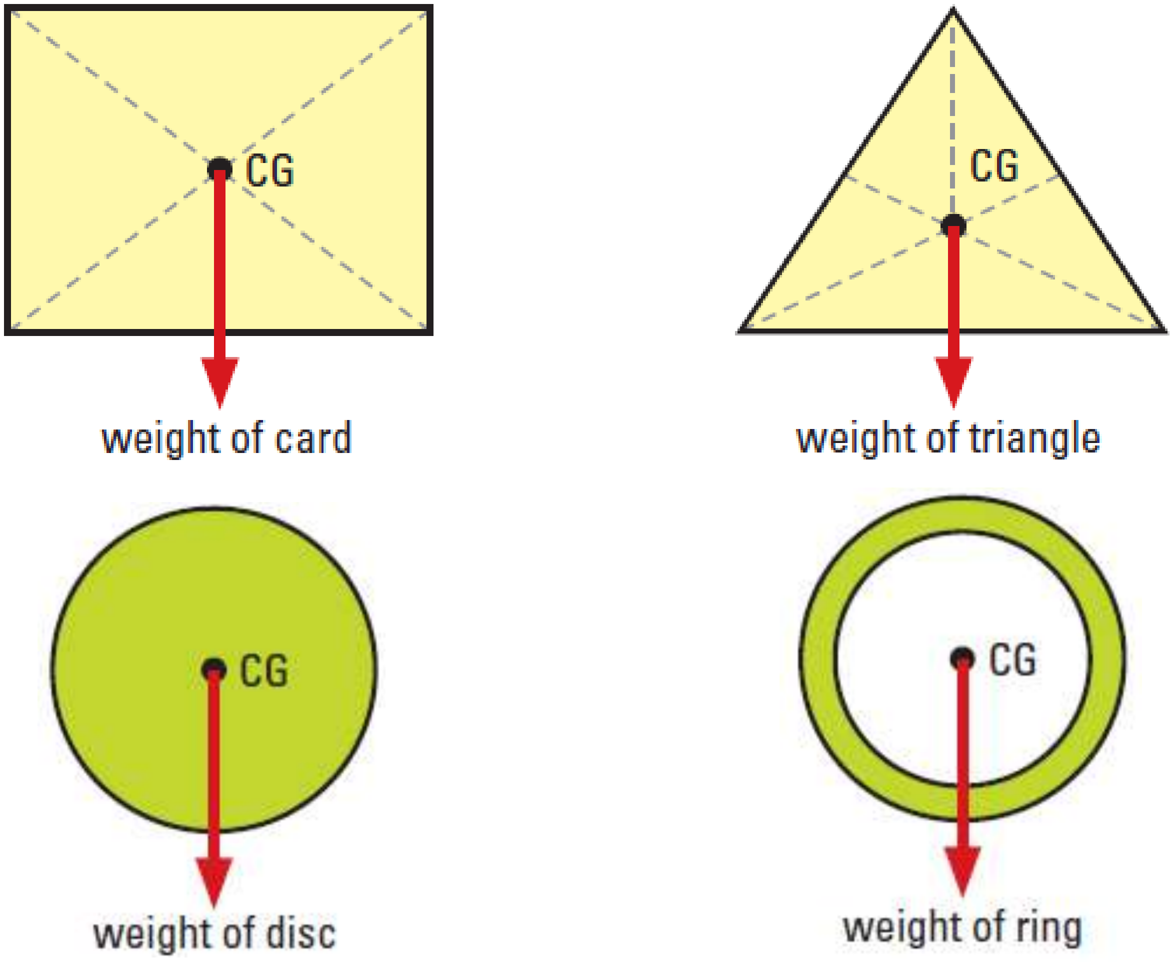
- Show understanding that the weight of a body may be taken as acting at a single point known as its center of gravity
- Describe quantitatively the effect of the position of the center of gravity on the stability of objects

CENTER OF GRAVITY

- The center of gravity of an object is the point through which the entire weight of the object appears to act.



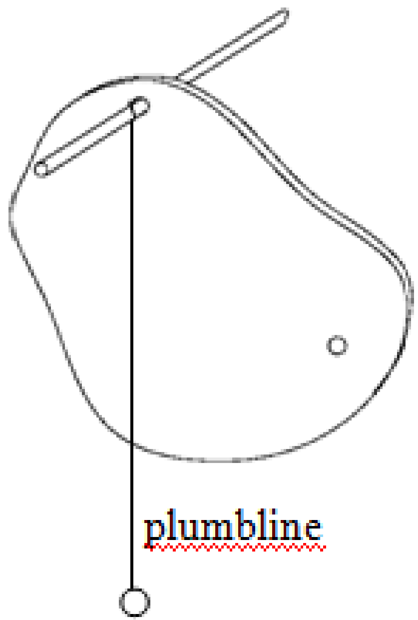
EXAMPLES OF CENTER OF GRAVITY FOR REGULAR-SHAPED OBJECTS



What about irregular-shaped objects?

Apparatus: Irregularly-shaped card, optical pin, string, pendulum bob, retort stand, wooden blocks, boss and clamp, set square

Diagram:



Procedure:

1. Make two holes in the lamina.
2. Suspend the lamina from the optical pin through one of the holes as shown.
3. Suspend the plumbline from the pin and mark the position of the plumbline on the lamina.
4. Repeat Step 2 and 3 for the other hole.
5. Draw lines on the lamina representing the positions of the plumbline.
6. Label the intersection of the two lines as X, the position of the centre of gravity of the lamina.
7. Perform a check by repeating steps 2 and 3 with a third hole to confirm the position of the centre of gravity of the lamina.

Metre rule

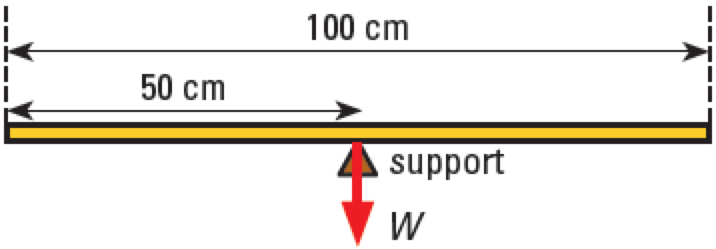


Figure 5.17 The ruler is in equilibrium when supported at its centre of gravity.

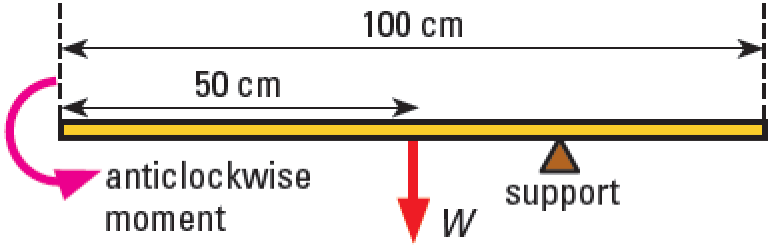


Figure 5.18 There is a resultant anticlockwise moment about the support which causes the ruler to topple to the left.

- For a regular object such as a uniform metre rule, the center of gravity is at the center of the object
- When the object is supported at that point, it will be balanced
- If it is supported at any other point, it will topple because there will be a resultant moment about the point of support due to the weight

Worked example

Worked Example 5.6

Figure 5.20 shows that a 100 cm long uniform rod AB of weight 10 N is pivoted at A. An irregular solid of weight *W*, is suspended 30 cm from end B. End B is supported by a spring balance which reads 19 N. Calculate the weight of the irregular solid.

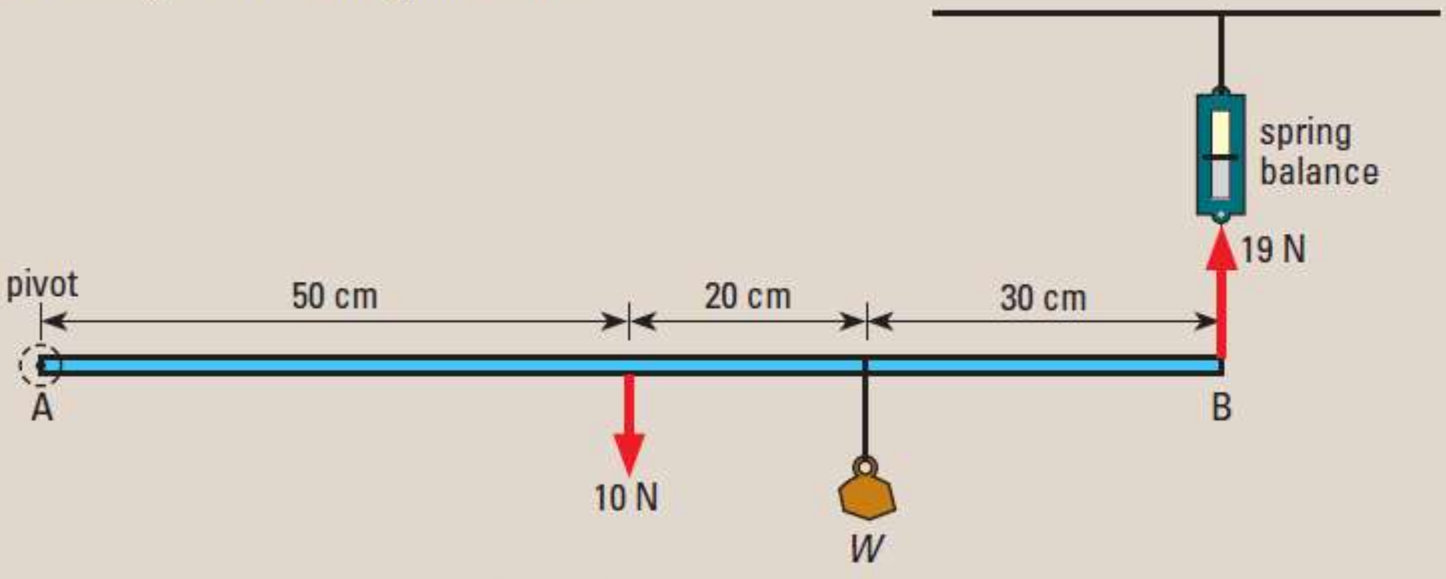
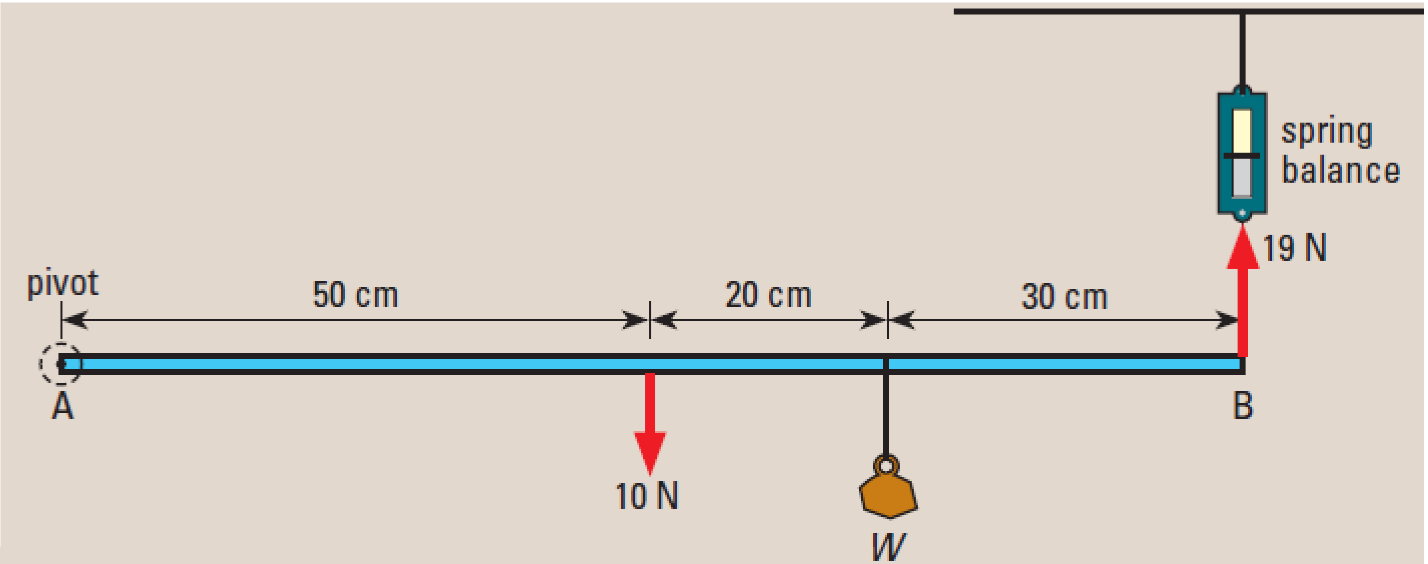


Figure 5.20

WORKED EXAMPLE



Solution

The weight of the rod, 10 N, acts at the centre of the rod.

By the principle of moments,

Sum of clockwise moments about A = Sum of anticlockwise moments about A

$$(W \times 70\text{ cm}) + (10\text{ N} \times 50\text{ cm}) = 19\text{ N} \times 100\text{ cm}$$

$$(W \times 70\text{ cm}) + 500\text{ N cm} = 1900\text{ N cm}$$

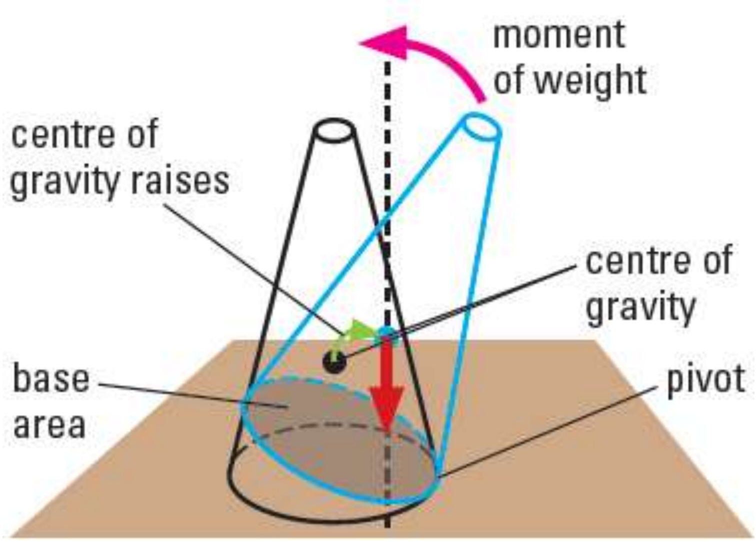
$$W \times 70\text{ cm} = 1400\text{ N cm}$$

$$W = 20\text{ N}$$

STABILITY

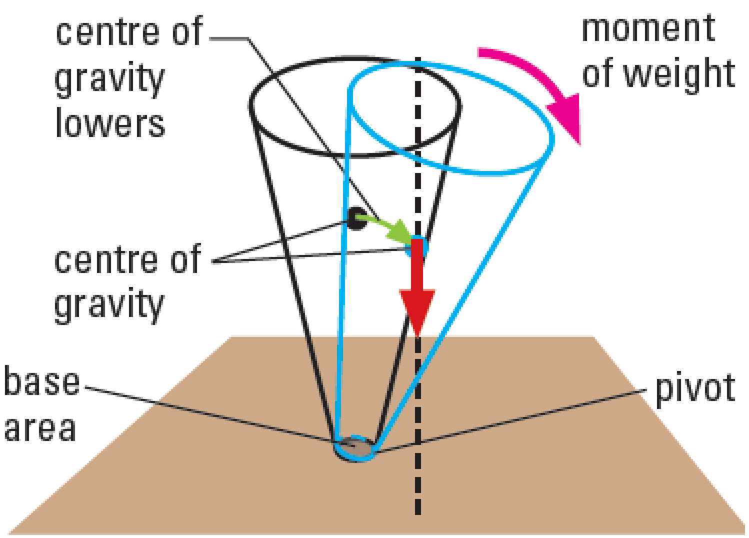
- Stability is a measure of the body's ability to maintain its original position.
  - Stable equilibrium
  - Unstable equilibrium
  - Neutral equilibrium

STABLE EQUILIBRIUM



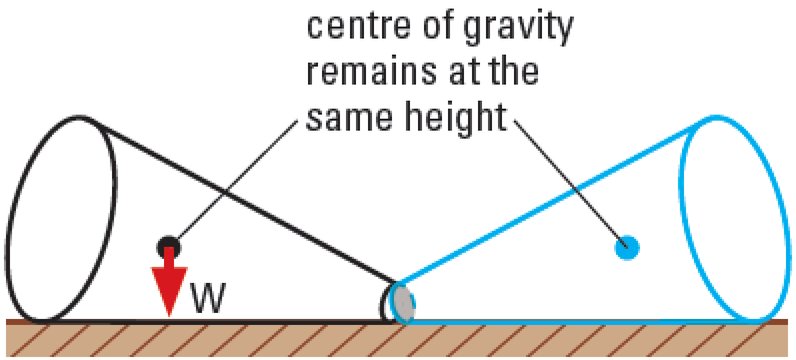
Stable equilibrium
• The frustum can be tilted through quite a big angle without toppling • Its center of gravity is raised when it is displaced. • The vertical line through its center of gravity still falls within its base • Its weight has a moment about the pivot which causes it to return to its original position

UNSTABLE EQUILIBRIUM



Unstable equilibrium
• The frustum will topple with the slightest tilting. • Its center of gravity is lowered when it is displaced. • The vertical line through its center of gravity falls outside its base. • Its weight has a moment about the pivot which causes it to topple.

NEUTRAL EQUILIBRIUM

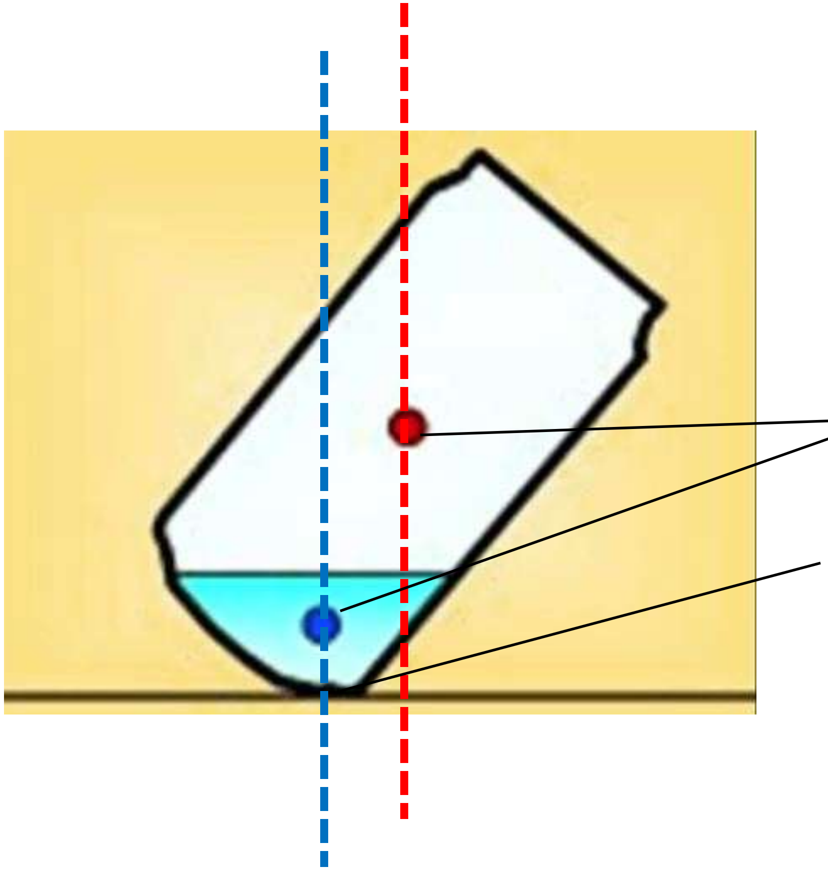


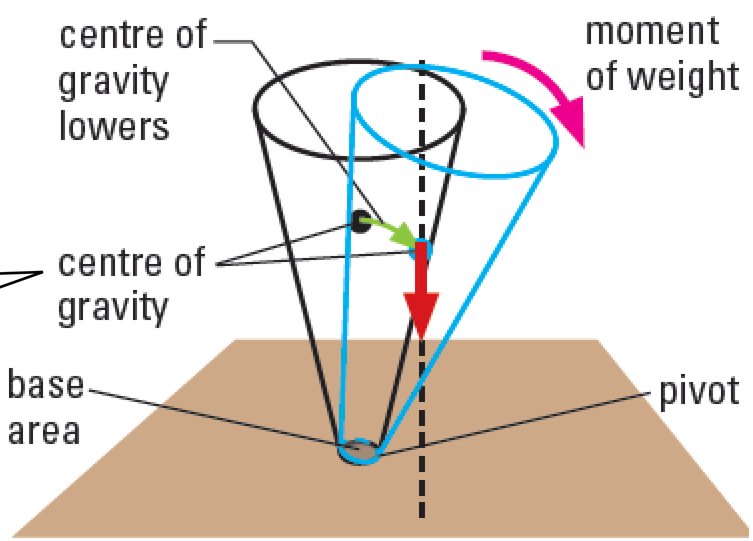
Neutral equilibrium
• The frustum will roll about but does not topple • Its centre of gravity remains at the same height when it is displaced. • The body will stay in any position to which it has been displaced.

COKE CAN

- How is the can able to stand?
- Which equilibrium do you think the can is in?

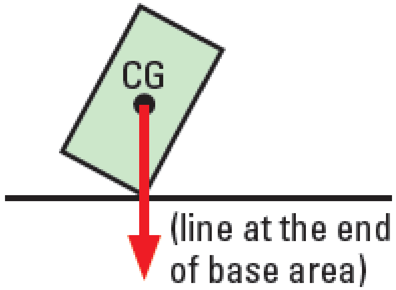
EXPLANATION



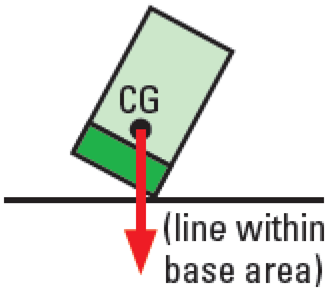


CONDITION FOR STABILITY

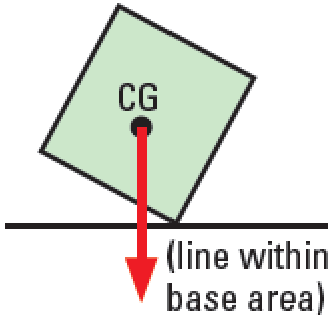
- To make a body more stable
  - Lower its centre of gravity
  - Increase the area of its base



This box is at the point
of tipping over



A heavy base(green area) lowers the center of gravity so the box does not tip over



A broader base makes the box more difficult to tip over

STABILITY

Figure 5.25a unstable

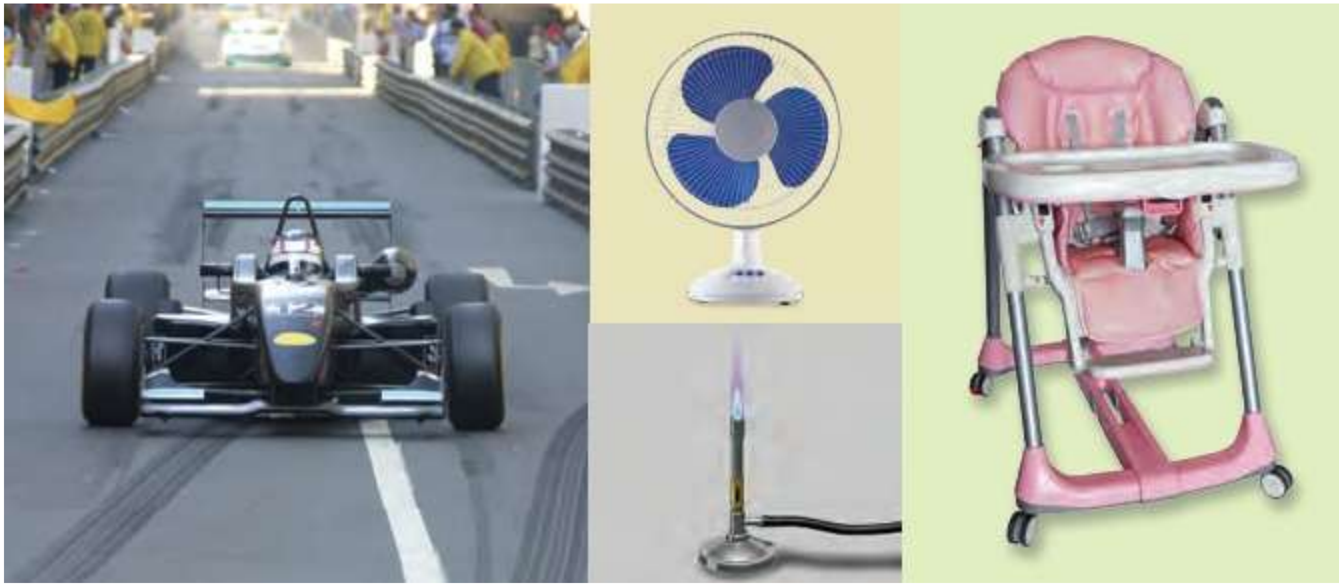
Figure 5.25b base area increased

Figure 5.25c centre of gravity lowered by adding lead to base

Real life applications

- It is for reasons of stability that the luggage compartment of a tour bus is located at the bottom and not on the roof
- Extra passengers are similarly not allowed on the upper deck of a crowded double-decker bus.

REAL LIFE APPLICATIONS

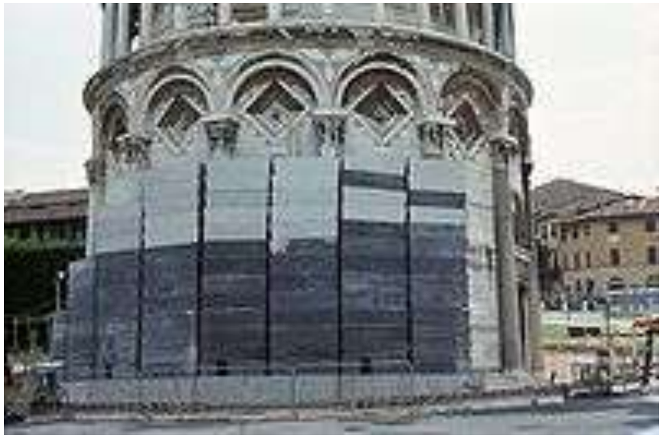


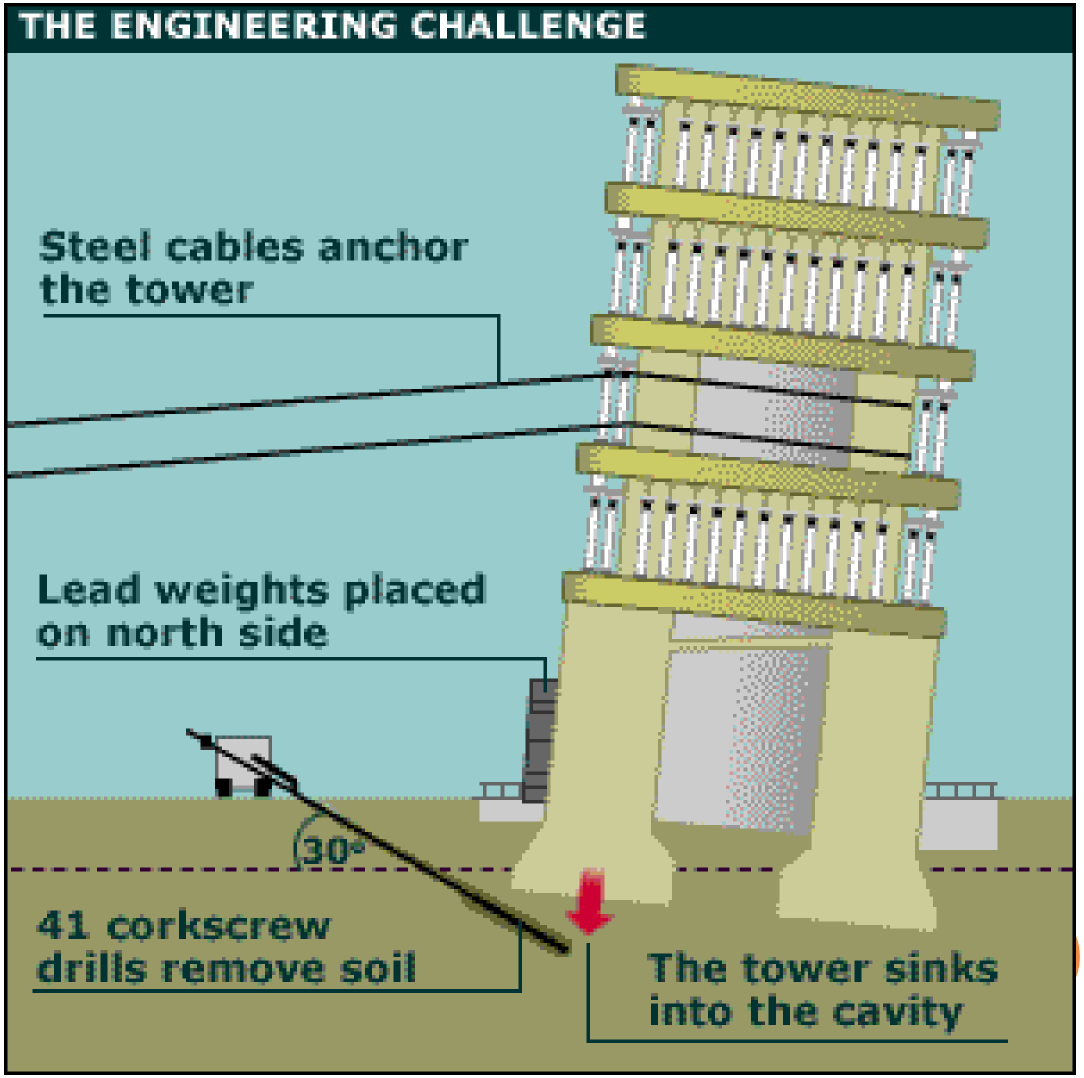
- Racing cars are built low and broad for stability
- Bunsen burners, table lamps and fans are designed with large, heavy bases to make them stable.
- The legs of a baby's highchair are set wide apart so that the chair is stable.

THE LEANING TOWER OF PISA

- Height: 55.86m
- Angle of slant: 3.96 degrees

STABILIZING THE LEANING TOWER OF PISA





Try this at home…

Is it possible to balance a coin on a dollar note?