# Spring Scales

Turn off all electronic devices



## Observations about Spring Scales

They move downward during weighing

They take a little time to settle

They're only accurate when everything is at rest



## 4 Questions about Spring Scales

1. What exactly is a spring scale measuring?
2. How does a spring scale measure weight?
3. What is scale's dial or meter actually reporting?
4. Why must you stand still on a spring scale?



## Question 1

Q: What exactly is a spring scale measuring?

A: The scale measures the weight of the object being weighed

Each object has a mass and a weight

- An object's mass does not depend on its location
- That object's weight is:

$$\text{weight} = \text{mass} \cdot \text{acceleration due to gravity}$$

- acceleration due to gravity varies slightly with location on Earth,
- acceleration due to gravity varies greatly with location in the universe,
- so an object's weight depends on its location



## Mass as a Measure

Mass is an excellent measure of an object's matter content

- The object's mass doesn't depend on its location

An object's mass can be measured directly:

- Exert a known force on the object
- Measure the object's acceleration
- Divide the force by the acceleration to find the mass

Alas, making that measurement is technically difficult



## Weight as a Measure

Weight is a problematic measure of an object's matter content

- The object's weight depends on location
- The object's mass can be determined from its weight,
- but only when the local acceleration due to gravity is known accurately

An object's weight must be measured indirectly:

- The object's weight is the force gravity exerts on the object
- There is no direct way to measure that weight

Fortunately, measuring weight indirectly is easy and accurate!

- Spring scales measure weight, not mass, but they do it well

# Question 2

Q: How does a spring scale measure weight?

A: The scale measures the upward force needed for equilibrium

Spring scale measures an object's weight using equilibrium

- It exerts an upward force on the object
- It adjust that force until the object is in equilibrium
- It measures the amount of that upward force
- It reports that amount as the object's weight



# Using a Spring to Measure Weight

Springs can exert adjustable, measurable forces

When an object is at equilibrium,

- individual forces on the object sum to zero—they cancel perfectly
- the object is inertial—it moves at constant velocity and may be motionless

To measure the object's weight, a spring scale

- uses a spring to support the object's downward weight
- allows spring and object to achieve motionlessness at equilibrium
- reports the spring's upward force on the object as the object's weight



# Question 3

Q: What is scale's dial or meter actually reporting?

A: How far the spring has distorted during the weighing process

A free spring adopts its equilibrium length or shape

When distorted, the spring's ends experience forces that

- act to restore the spring to its equilibrium length or shape
- make the equilibrium length or shape a stable equilibrium
- are proportional to the distortion



# Hooke's Law

The restoring force on the end of a spring is equal to a spring constant times the distance the spring is distorted. That force is directed opposite the distortion.

$$\text{restoring force} = -\,\text{spring constant} \cdot \text{distortion}$$

A stiff spring has a large spring constant

A soft spring has a small spring constant



# A Spring Scale

To weigh an object, a spring scales

- supports the object with a spring,
- lets the object become motionless at equilibrium,
- measures the distortion of its spring,
- determines the force the spring is exerting on the object to support it,
- and reports that force.

To determine the spring's force from its distortion, the scale

- must know its spring's spring constant with great accuracy
- must have been calibrated by studying known forces and distortions



# Question 4

Q: Why must you stand still on a spring scale?

A: It reports your correct weight only when you are in equilibrium

The scale actually reports the upward force its spring exerts on you

- If you're at equilibrium, the amount of spring force equals your weight
- If you are below equilibrium, that spring force exceeds your weight
- If you are above equilibrium, that spring force is less than your weight
- If you are accelerating, you are not at equilibrium!

For the scale to report your weight correctly,

- you must not bounce on a scale!
- you must wait for the scale to settle at equilibrium!

# Oscillation

When you first place a load on a scale, it bounces

- It accelerates toward a new equilibrium
- It then coasts through that equilibrium
- It then accelerates back toward the new equilibrium
- It keeps accelerating toward equilibrium but overshoots many times

It oscillates or vibrates around the new stable equilibrium

- To settle at equilibrium, it must get rid of its extra energy
- Friction and air resistance help it settle



# Summary about Spring Scales

- The spring stretches during weighing
- This stretch is proportional to object's weight
- The scale measures the spring's stretch
- The scale reports that stretch as object's weight