Gravity

"the stuff falls are made of"

Gravity

- Besides developing the three laws of motion, Newton also examined the motion of the planets and the moon.
- He wondered about the force that kept the Moon in its orbit around the Earth.

Gravity

- Newton was also thinking about the problem of gravity.
- Since falling bodies accelerate, they must have some force acting on them.
- That force is what we call gravity.

Gravity

- Whenever a body has a force exerted ***on*** it, that force is exerted ***by*** some other body.
- Newton concluded that it must be the Earth itself that exerts the gravitational force on objects at its surface.

Gravity

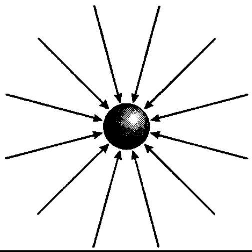
- Many thinkers at the time had problems with Newton's theory.
- How could a force act without physical contact?
- However, we know this to be true.

Gravity

- Newton also showed that this force decreased with distance.
- Michael Farady introduced a concept of "field lines" to represent the strength and direction of a force.
  - More field lines per unit area represent a stronger field.

Gravitational Field Lines

- If we apply this concept to gravity (and the Earth) we can draw a diagram as follows:



Gravitational Field Strength

- The gravitational field strength is defined as the gravitational force that a "test mass" (1 kg) would experience at some point in the field.

$$g = \frac{F_g}{m}$$

Units= N/kg or m/s^2

Value of g

- Near the surface of the Earth the value of g is 9.8 N/kg (or equivalently 9.8 m/s^2)
- This value varies depending on the altitude that you are at.
- On the moon, g is about one sixth less than on Earth.

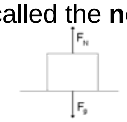
Weight

- What do we mean by **weight**?
- The weight of an object is the magnitude of the force of gravity on the object.

$$weight = F_g = mg$$

Apparent Weight

- A stationary object that is sitting on the ground is being pulled down by the gravitational force.
- However, since the object is not accelerating, there must be an equivalent force pointing up on the object.
- That force is called the **normal force** (F_N).



Normal Force

- These two forces must be equal in magnitude, or the object will be accelerating.

$$F_{net} = F_N + F_g = ma$$
$$a = 0$$
$$F_{net} = F_N + F_g = 0$$
$$F_N = -F_g$$
$$\therefore \quad |F_N| = |F_g|$$

More about Weight

- Now consider a person standing in a moving elevator.
- If the elevator is traveling at a constant velocity, then acceleration is 0.
- Therefore, we have the same situation as a stationary object sitting on a surface.

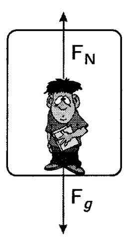


Diagram A
constant velocity
($a = 0$ m/s^2)
$F_{net} = ma$
$F_N + F_g = 0$
$F_N = -F_g$
$|F_N| = |F_g|$

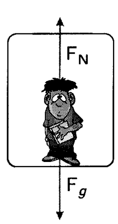


Diagram B
accelerated motion upward
($a > 0$)
$F_{net} = ma$
$F_N + F_g = (+)$
$F_N = (+) + (-F_g)$
$= (+) + (+)$
$\therefore |F_N| > |F_g|$

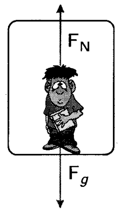


Diagram C
accelerated motion
downward
($a < 0$)
$F_{net} = ma$
$F_N + F_g = (-)$
$F_N = (-) + (-F_g)$
$= (-) + (+)$
$\therefore |F_N| < |F_g|$

Free Fall

- If an object is in free fall (the only force acting on it is gravity) then we can calculate the acceleration due to gravity (assuming there is no air resistance).

Free Fall

$$F_{net} = ma$$
$$F_{net} = F_{applied}$$
$$F_{applied} = F_g$$
$$ma = mg$$
$$a = g$$

Air Resistance

- However, air resistance is a real thing and does play apart in how objects fall.
- In free fall, air resistance varies with the square of the speed:

$$F_{air} \propto v^2$$

- As speed increases, air resistance also increases.

Terminal Velocity

- Eventually the air resistance equals the force of gravity and the object reaches **terminal velocity**.

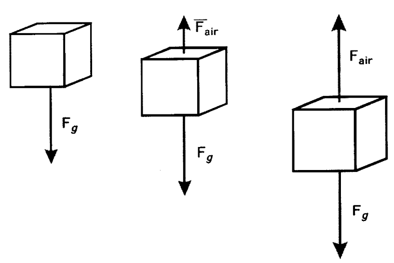


Diagram a
Free fall begins (no air resistance)
$F_{net} = F_g$
$a = g$

Diagram b
Object falling in air, resistance increases
$F_{net} = F_g + F_{air}$
a =< g

Diagram c
As velocity increases, air resistance increases until
$F_{air} = -F_g$
$F_{net} = 0$ and $a = 0$
Velocity is constant (terminal velocity)