A PHYSICS LESSON

Forces, Motion & Gravity

Understanding $F = ma$ — the formula that explains how everything moves

$$F = m\,a$$

What is a Force?

A force is simply a push or a pull on something.

PUSH

Shoving a shopping cart down the aisle

PULL

Tugging a wagon behind you

GRAVITY

Earth pulls an apple down to the ground

Forces can speed things up, slow them down, or change their direction.

Newton's Second Law

$$F = m \cdot a$$

Force = Mass × Acceleration

If you know two of them, you can find the third.

Breaking It Down

F

Force

Newtons (N)

How hard you push or pull. One Newton is about the weight of a small apple.

m

Mass

Kilograms (kg)

How much stuff is in an object. A bowling ball has more mass than a beach toy.

a

Acceleration

m/s^2

How quickly speed is changing. Flooring the gas in a car is high acceleration.

Bigger force → bigger acceleration. *Heavier object → needs more force to move the same way.*

$F = m \cdot a$ in Real Life

Same formula, three familiar situations.

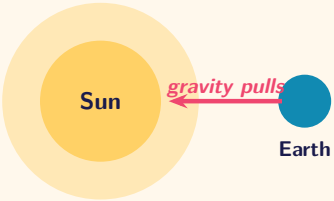
Pushing a shopping cart	A gentle push gives small acceleration. Push harder, and the cart speeds up faster.	`bigger F` → `bigger a`
Bike vs. truck	Push a bike and a truck with the same force. The bike zooms; the truck barely moves.	`bigger m` → `smaller a`
Kicking a ball	A soft tap barely moves the ball. A strong kick sends it flying.	`bigger F` → `bigger a`

Gravity: A Force That Pulls

Every object with mass pulls on every other object.

The Sun pulls the Earth.
The Earth pulls the Moon.
The Earth pulls you — and you pull the Earth back (just very, very gently).

> **Two rules of gravity**
>
> 1. More mass → stronger pull
> 2. Farther away → weaker pull



Gravity on Earth

When you drop something, Earth's gravity makes it fall faster and faster.

On Earth, $a = 9.80665$ m/s^2

$$F = m \cdot 9.80665$$

This force is what we call weight.

Every second something falls, it gets 9.81 m/s faster.

Try it: a 2 kg ball

Force of gravity on it?

$$F = 2 \cdot 9.80665 = 19.61 \text{ N}$$

After 1 second of falling?

$$v = 9.81 \text{ m/s} \ (\approx 35 \text{ km/h})$$

After 2 seconds?

$$v = 19.61 \text{ m/s} \ (\approx 71 \text{ km/h})$$

It keeps getting faster every second.

Newton's Law of Universal Gravitation

$$F = G\frac{m_1\, m_2}{r^2}$$

G

A tiny number (the gravity constant)

$m_1 \cdot m_2$

The two masses multiplied together

r

The distance between them

Double the distance → gravity becomes 4× weaker (because r is squared).

A Surprising Discovery

"Heavy and light things fall at the same speed."

A bowling ball and a feather, dropped in a vacuum, land at the exact same time.

Why? The math shows us:

$F = ma$ *Newton's 2nd Law* → $F = mg$ *Gravity's pull* → $ma = mg$ *Both equal F* → $a = g$ *Mass cancels out!*

No matter the mass, everything on Earth accelerates at the same $9.80665\ m/s^2$.

Galileo tested this by dropping balls from the Leaning Tower of Pisa about 400 years ago.

Code Example 1: A Falling Ball

Using $F = m \cdot a$ to simulate gravity pulling a ball toward the ground.

gravity.js

```
let y = 0;           // position (how high up)
let v = 0;           // velocity (speed + direction)
const m = 1;         // mass in kg
const g = 9.80665;   // Earth's gravity

function fall(dt) {
  const F = m * g;   // F = m · a
  const a = F / m;   // a = F ÷ m
  v += a * dt;       // speed up each tick
  y += v * dt;       // move by current speed
}
```

What happens

Tick 0 → v = 0
(ball stationary)

Tick 1 → v = 9.81
(1 sec later)

Tick 2 → v = 19.61
(2 sec later)

Speed keeps growing!

Notice: mass cancels out — $a = g$. Any ball falls the same way.

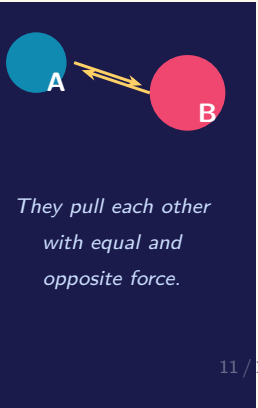
Code Example 2: Two Planets Pulling

Using Newton's law of gravitation: $F = G \cdot m_1 \cdot m_2 / r^2$

planets.js

```
const G = 1;  // gravity strength

function pull(a, b) {
  const dx = b.x - a.x;
  const dy = b.y - a.y;
  const r = Math.sqrt(dx*dx + dy*dy);
  // F = G · m1 · m2 / r^2
  const F = G * a.m * b.m / (r * r);
  // a = F / m  (from F = ma)
  a.ax += F * dx / r / a.m;
  a.ay += F * dy / r / a.m;
}
```



THREE BIG IDEAS

What You've Learned

1

$F = m \cdot a$

Push harder, it speeds up faster. Heavier things need more force.

2

Gravity is just a force

Everything with mass pulls. More mass, stronger pull.

3

Math becomes code

JavaScript can simulate planets and falling balls.

Now go experiment in the gravity simulator!