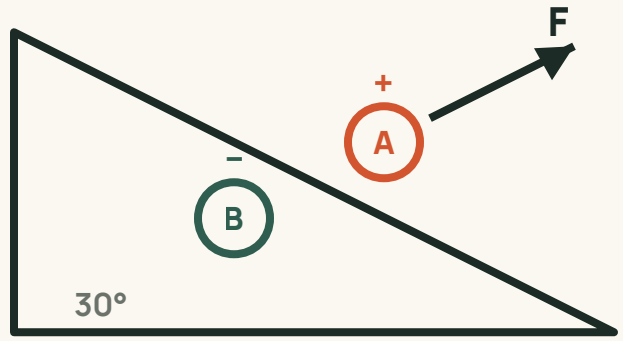
ELECTROSTATICS

The Coulomb force: balance & acceleration

When charges also feel gravity, tension or a push.



ESSENTIAL QUESTION

When a charged object sits still or speeds up, is this new physics — or just mechanics with one extra force?

LESSON MAP

One idea, built in four moves.

01

FRAME

The Coulomb force is just one more force on the diagram.

02

BALANCE

At rest, every force cancels: $\sum F = 0$.

03

THREE CHARGES

Free charges in a line settle by simple rules.

04

ACCELERATE

Speeding up together: $\sum F = ma$.

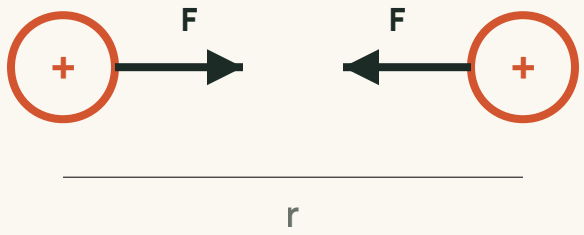
THE WHOLE TRICK

An electric problem, solved with mechanics. Draw the forces, name the state, then apply $\sum F = 0$ or $\sum F = ma$.

RECALL

The Coulomb force is just another force.

It acts along the line joining the charges — push apart if alike, pull together if opposite.



$$F = k\,\frac{q_1 q_2}{r^2}$$

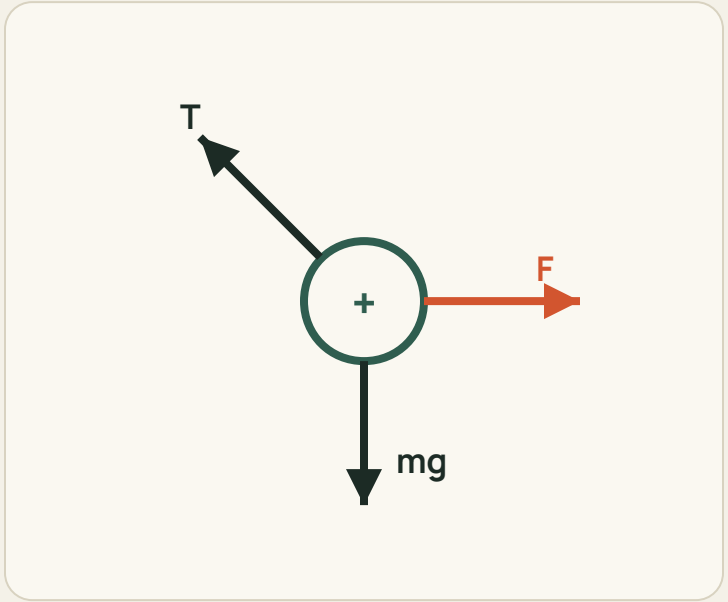
k is the electrostatic constant, q_1, q_2 the charge magnitudes, r their separation. Equal and opposite on the two charges — Newton's third law still holds.

METHOD

An electric problem, a mechanics method.

Charged bodies obey the same three steps as any force problem.

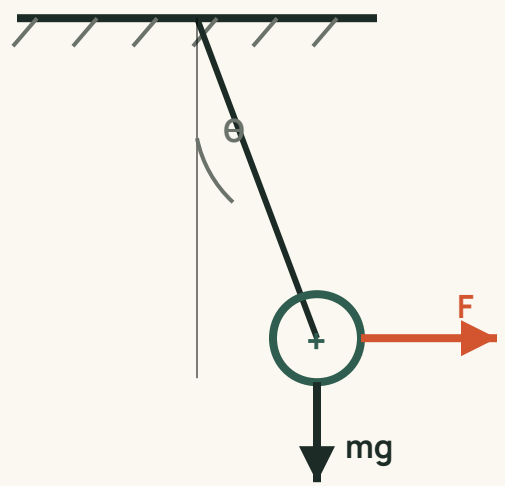
1. **Draw the free-body diagram.** Mark gravity, normal force, tension, friction — and the Coulomb force, like any other.
2. **Name the state.** At rest or constant velocity → equilibrium. Speeding up → accelerating.
3. **Apply the law.** Equilibrium → $\sum F = 0$. Accelerating → $\sum F = ma$. Then solve.



BALANCE

At rest, three forces close into a triangle.

A charged ball hangs by a string near a fixed charge; the string leans at angle θ.



Resolve along and across the string

$$T\cos\theta = mg$$

$$T\sin\theta = F$$

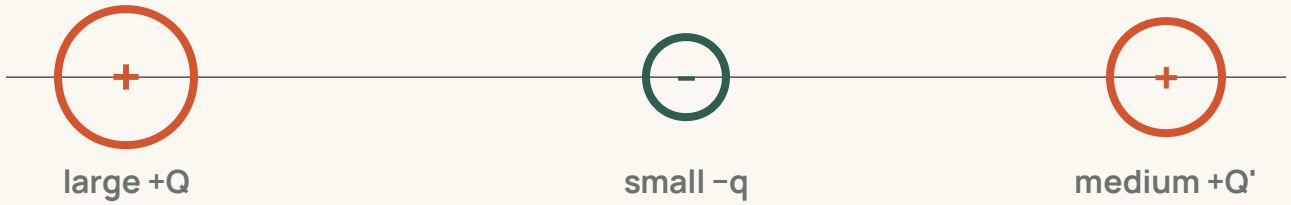
$$F = mg\tan\theta$$

The lean angle alone fixes the electric force. Tension follows: $T = \frac{mg}{\cos\theta}$.

THREE CHARGES

Three free charges settle by four rules.

If all three rest in equilibrium on their own, their layout is forced.



COLLINEAR

All three lie on one straight line.

SIGNS ALTERNATE

Two like charges flank one opposite charge.

SMALLEST INSIDE

The middle charge has the least charge.

NEARER THE SMALLER

The middle sits closer to the smaller outer charge.

DERIVE

The middle charge sits where the two pulls cancel.

Balance the forces on the inner charge — its sign and size drop out.

$$\frac{k\,(9Q)\,q}{r_1^2} = \frac{k\,(4Q)\,q}{r_2^2}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{9}{4}} = \frac{3}{2}$$

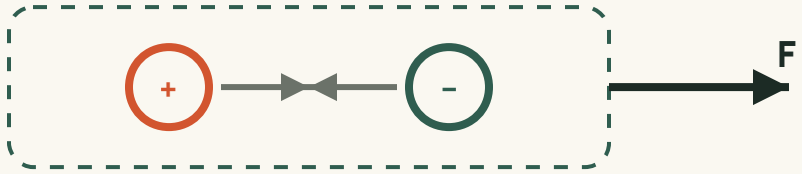
Closer to the smaller charge, as the rule promised. For all three to balance, the inner charge must be negative.

ACCELERATE

Moving together? Choose system or isolation.

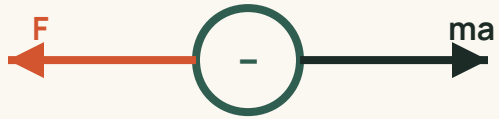
Two methods, one law: $\sum F = ma$.

SYSTEM METHOD



Internal Coulomb forces cancel: $F = (m_1 + m_2)\, a$.

ISOLATION METHOD



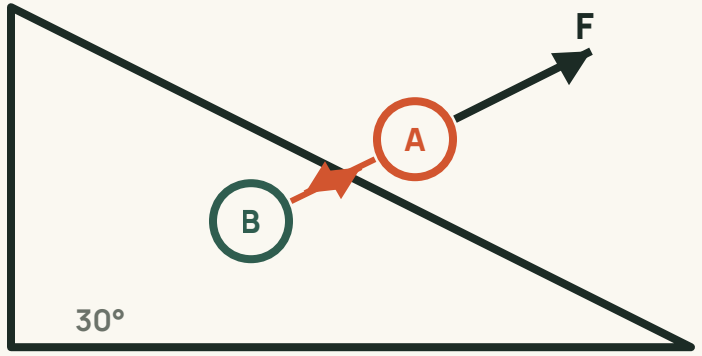
Cut one body free; now the Coulomb force does appear.

For the pair, the Coulomb force is internal; for one body, it is real.

APPLY

Two charges, one push, up a frictionless incline.

$A\,(+q)$ above, $B\,(-q)$ below, each mass m, kept a distance r apart by their attraction; F drives them up a $30°$ slope.



Isolate B (the attraction pulls it up-slope)

$$\frac{kq^2}{r^2} - mg\sin 30° = ma$$

Isolate A (Coulomb pulls it down-slope)

$$F - \frac{kq^2}{r^2} - mg\sin 30° = ma$$

$$F = \frac{2kq^2}{r^2}$$

CHECK

Three traps to avoid.

Most mistakes here are mechanics mistakes, not electricity ones.

01

DON'T DROP A FORCE

Gravity and the normal force are still there. The Coulomb force is added, not a replacement.

02

PICK THE RIGHT BODY

Use the system to find external F; isolate one body to find an internal force or a shared a.

03

MIND THE DIRECTION

Like charges repel, opposite attract. Get the arrow's direction right before resolving.

Same charges repel, opposite charges attract — always along the joining line.

SUMMARY

Treat the Coulomb force like any other force: draw it on the free-body diagram, decide whether the body is balanced or accelerating, then apply $\sum F = 0$ or $\sum F = ma$. Electric problem, mechanics method.