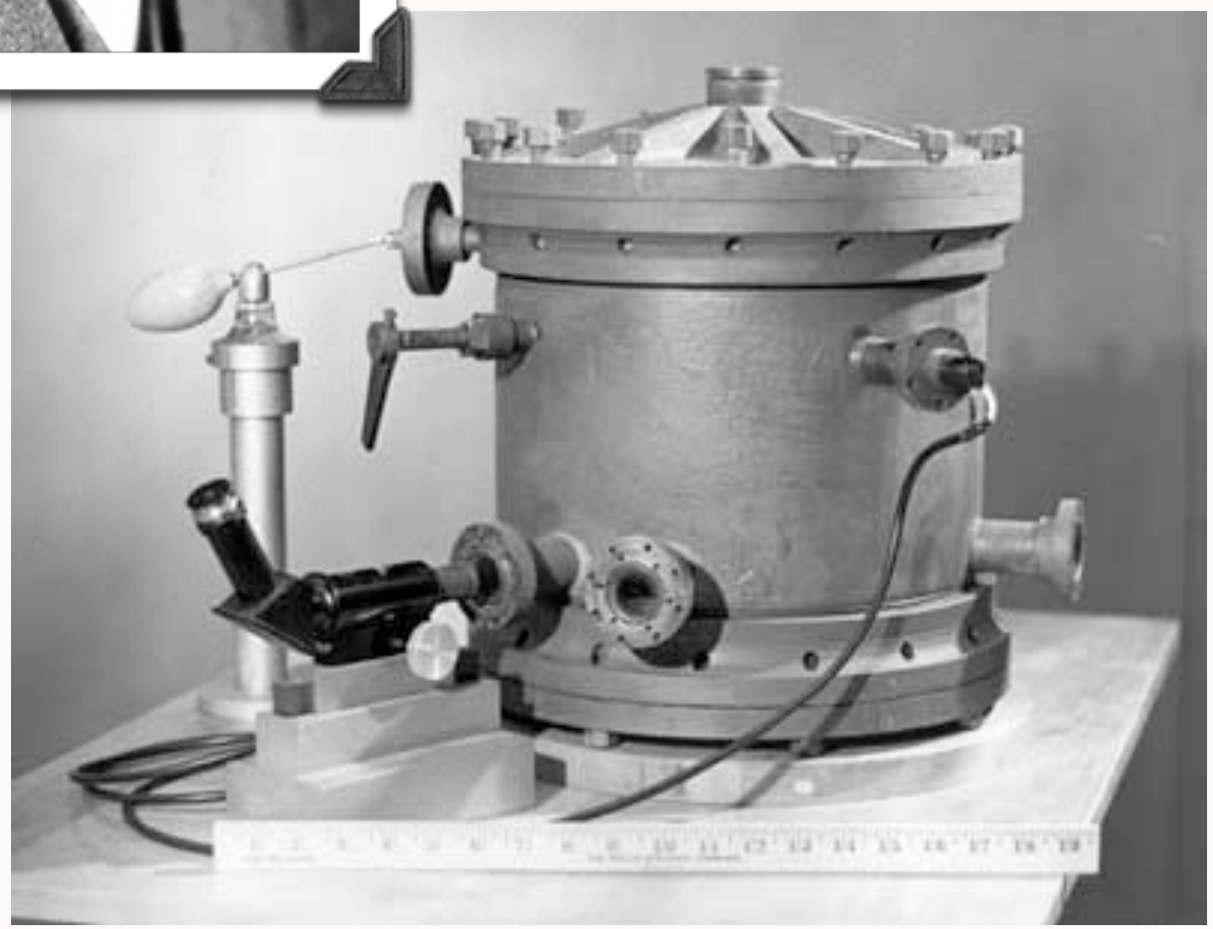
ELECTROSTATICS

THE COULOMB

- Standard unit of charge
- The charge on a single electron = -1.6 x10^{-19} C
- a proton... 1.6 x10^{-19} C
- or... 1 coulomb is 6.2 x10^{18} electrons

ELECTRIC CHARGE



- Robert A. Millikan
- Oil Drop experiment published in 1913
- found the quantum value of electric charge

ELECTRIC FORCE

- Coulomb's Law
- Force
- Q -"Source" charge
- q -test charge
- r -distance (radius)
- k= $9 \times 10^9\ Nm^2/C^2$

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

TWO CHARGES - LINEAR

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

TWO CHARGES - LINEAR

Q = -8.6 μC

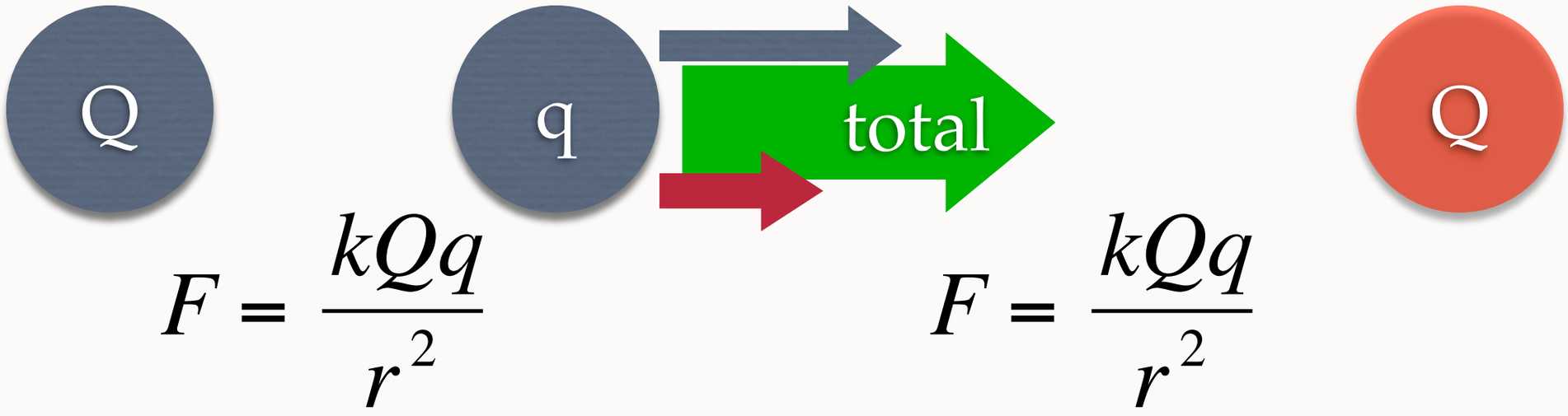
Q = +5.9 μC

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

$$F = \frac{[(9\times10^{9})(-8.6\times10^{-6})(5.9\times10^{-6})]}{(0.4^{2})}$$

F = - 2.85 N

MULTIPLE CHARGES -LINEAR



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

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

MULTIPLE CHARGES -LINEAR

Q = -2.1 μC **Q = -4.2 μC** **Q = +8.4 μC**

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

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

$$\frac{F= [(9x10^{9})(-2.1x10^{-6})(-4.2x10^{-6})]}{(0.15\ ^{2})}$$

$$\frac{F= [(9x10^{9})(8.4x10^{-6})(-4.2x10^{-6})]}{(0.3\ ^{2})}$$

3.53

-3.53

MULTIPLE CHARGES -LINEAR

Q = -2.1 μC **Q = -4.2 μC** **Q = +8.4 μC**

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

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$$\frac{F= [(9x10^{9})(-2.1x10^{-6})(-4.2x10^{-6})]}{(0.15\ ^{2})}$$

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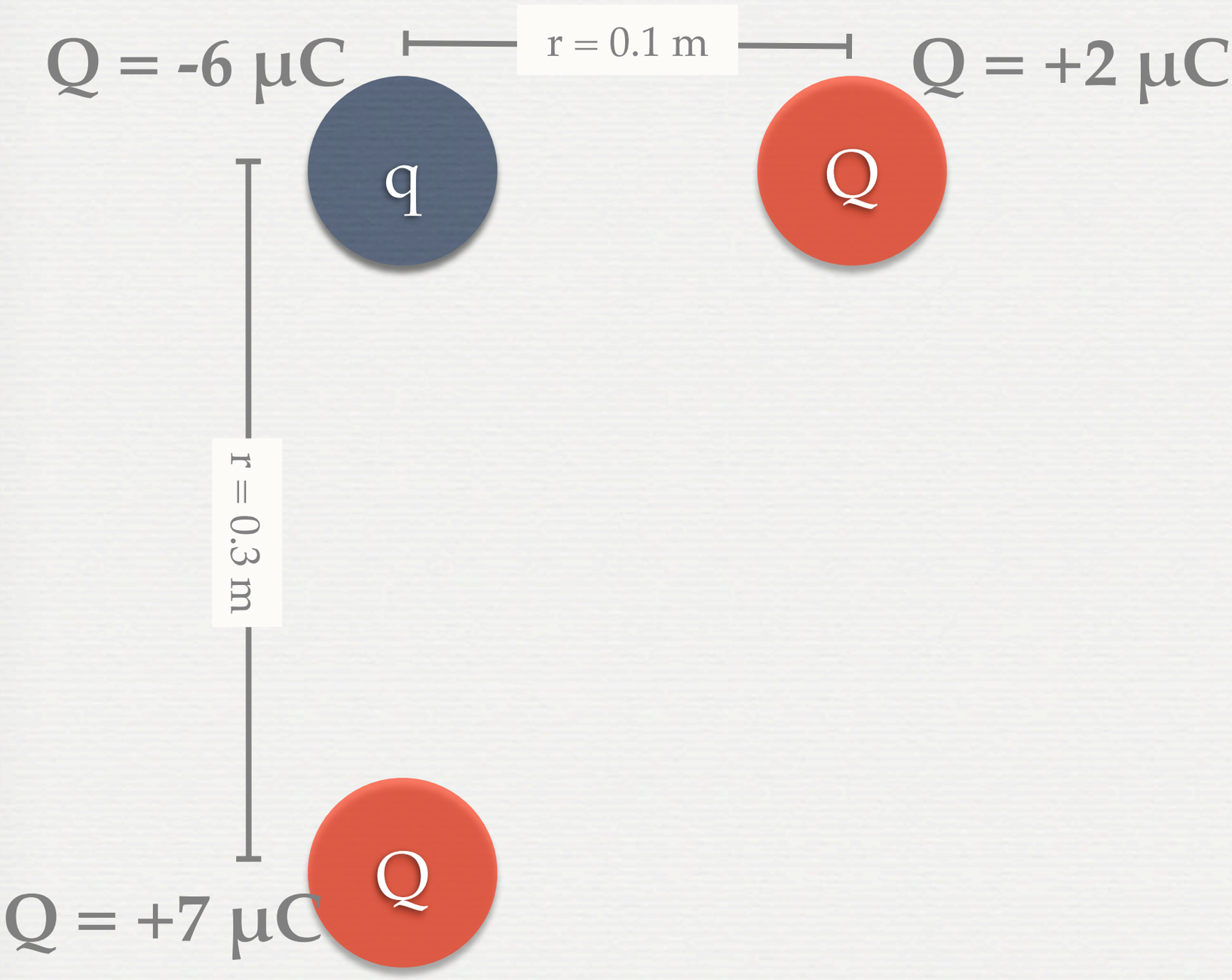
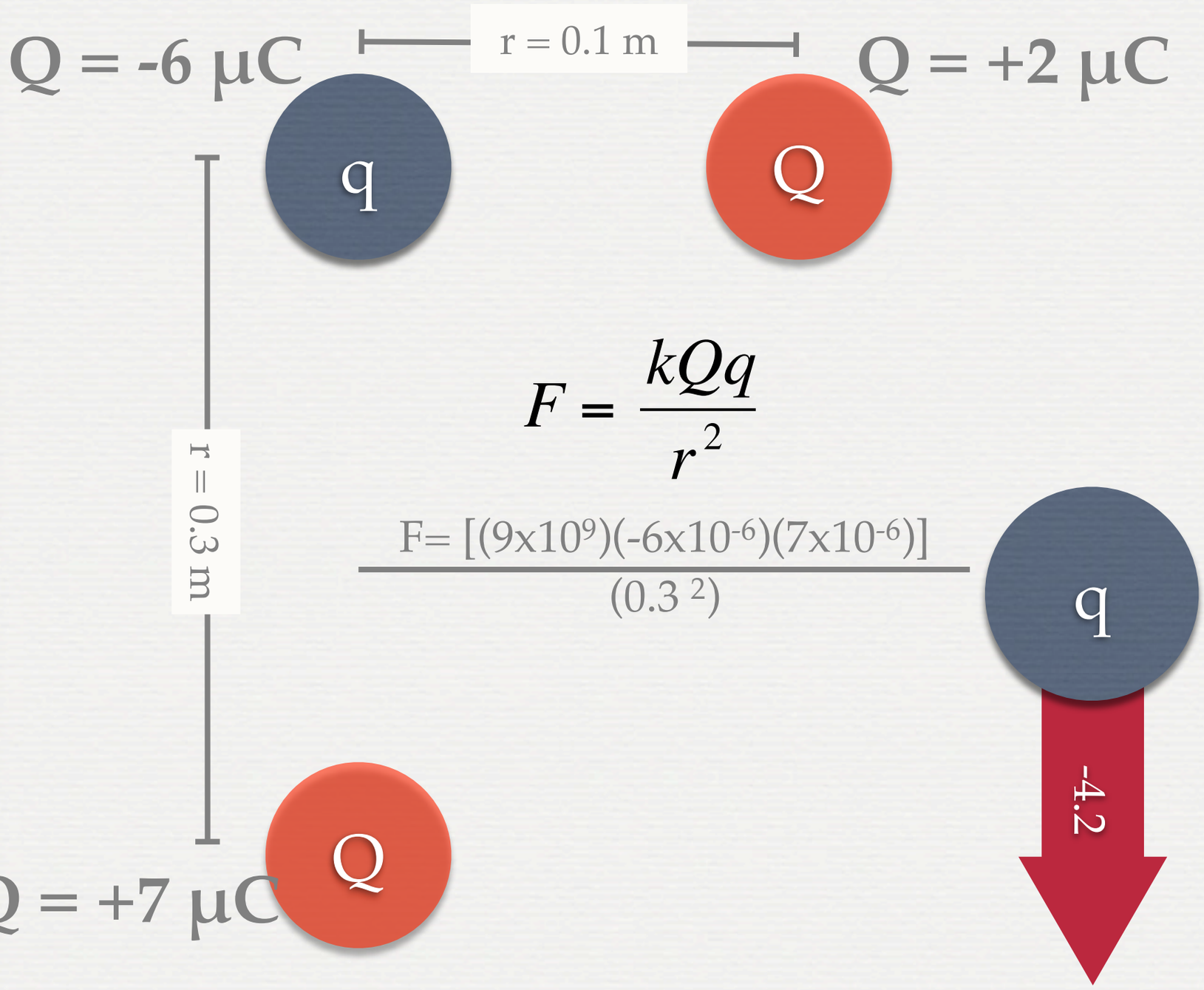
2 FORCES - NON LINEAR



2 FORCES - NON LINEAR



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

$$F = \frac{[(9x10^{9})(-6x10^{-6})(7x10^{-6})]}{(0.3^{2})}$$

2 FORCES - NON LINEAR

Q = -6 μC — r = 0.1 m — Q = +2 μC

q Q

r = 0.3 m

Q = +7 μC

Q

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

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

$$\frac{F= [(9x10^{9})(2 x10^{-6})(-6 x10^{-6})]}{(0.1^{2})}$$

$$\frac{F= [(9x10^{9})(-6x10^{-6})(7x10^{-6})]}{(0.3^{2})}$$

q

-10.8

-4.2

2 FORCES - NON LINEAR

Q = -6 μC — r = 0.1 m — Q = +2 μC

q Q

r = 0.3 m

Q = +7 μC

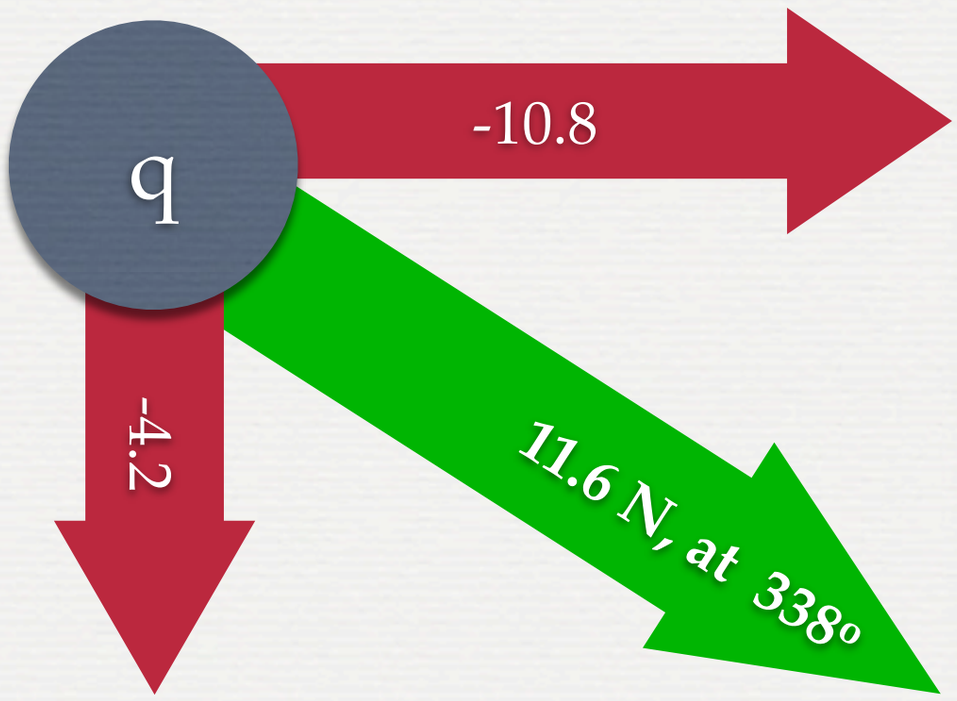
Q

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

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

$$\frac{F= [(9x10^{9})(2 x10^{-6})(-6 x10^{-6})]}{(0.1^{2})}$$

$$\frac{F= [(9x10^{9})(-6x10^{-6})(7x10^{-6})]}{(0.3^{2})}$$



LOOK FAMILIAR?

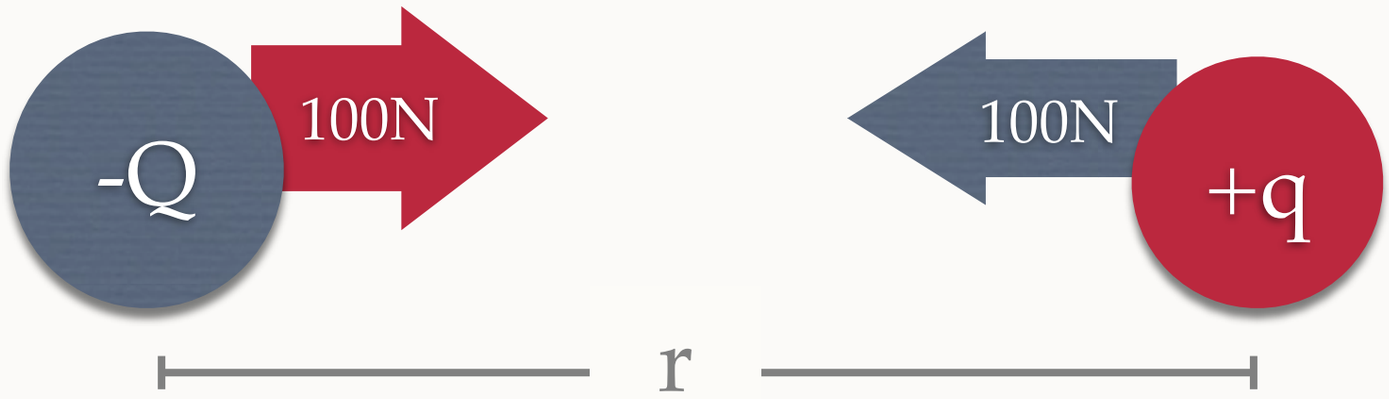
The relationship between charges is very similar to the force of gravity between masses, although many times stronger.

Between Planets

$$F_g = \frac{GMm}{r^2}$$

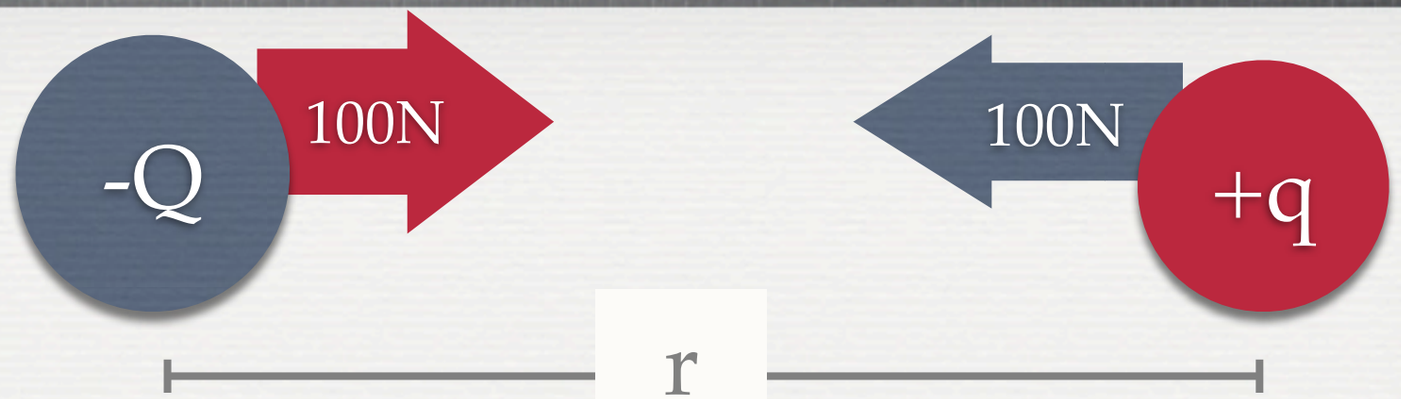
- What is the force of attraction between the **5.97×10^{24}kg Earth** and the **7.24×10^{22}kg moon** that is **3.84×10^{8}m** away?
- **1.955×10^{20} N**
- What is the result of this force?

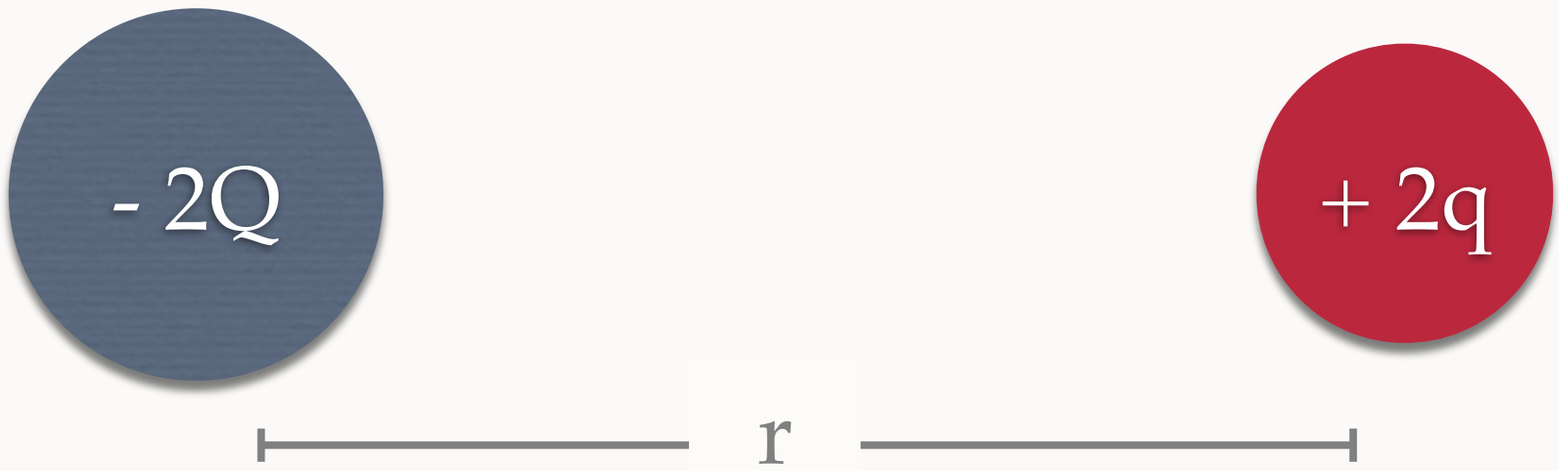
RELATIVE CHANGES



- These two charges have a force between them of 100N

RELATIVE CHANGES

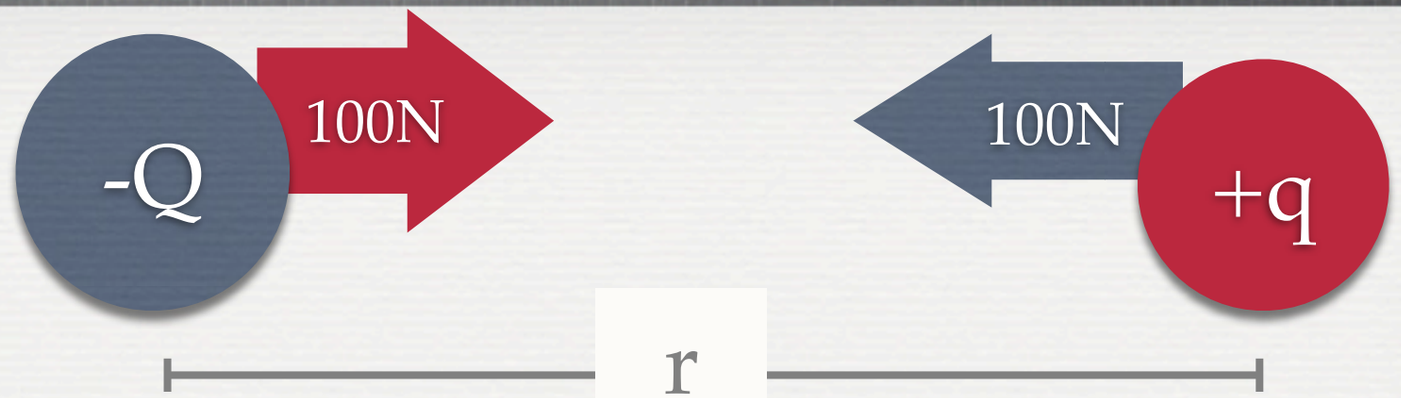


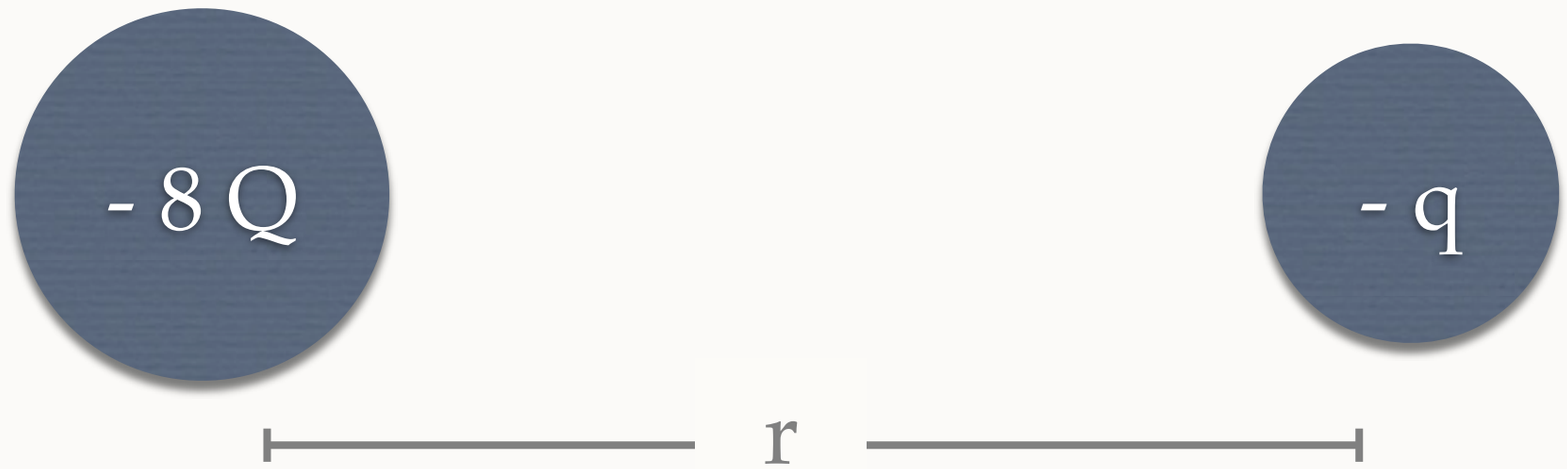


- What is the force on the left charge?

400N

RELATIVE CHANGES

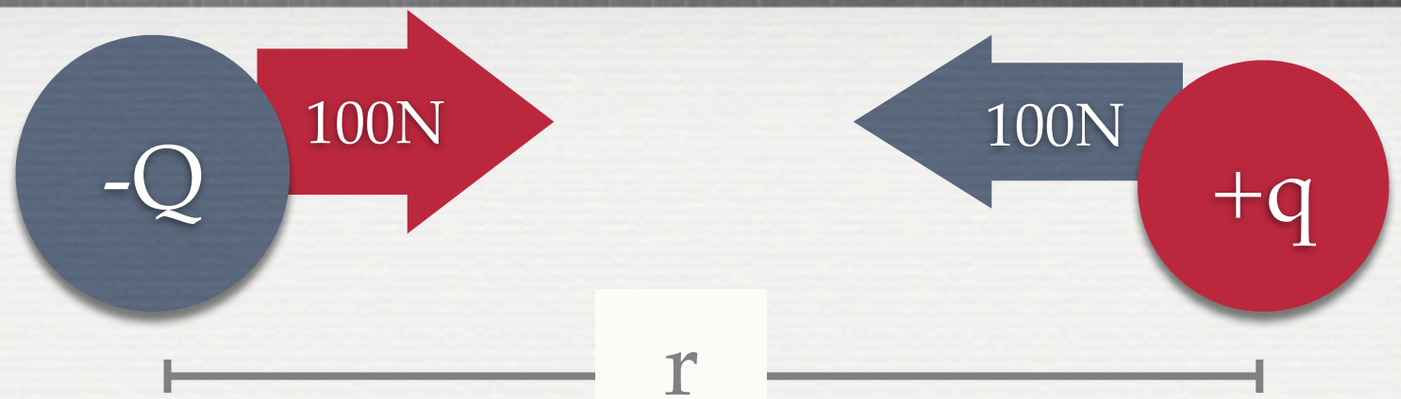


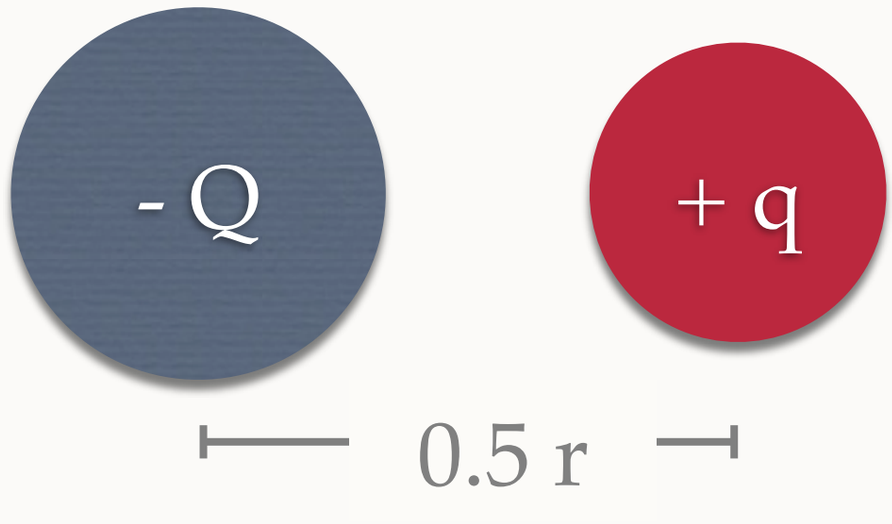


- What is the force on the left charge?

800N

RELATIVE CHANGES

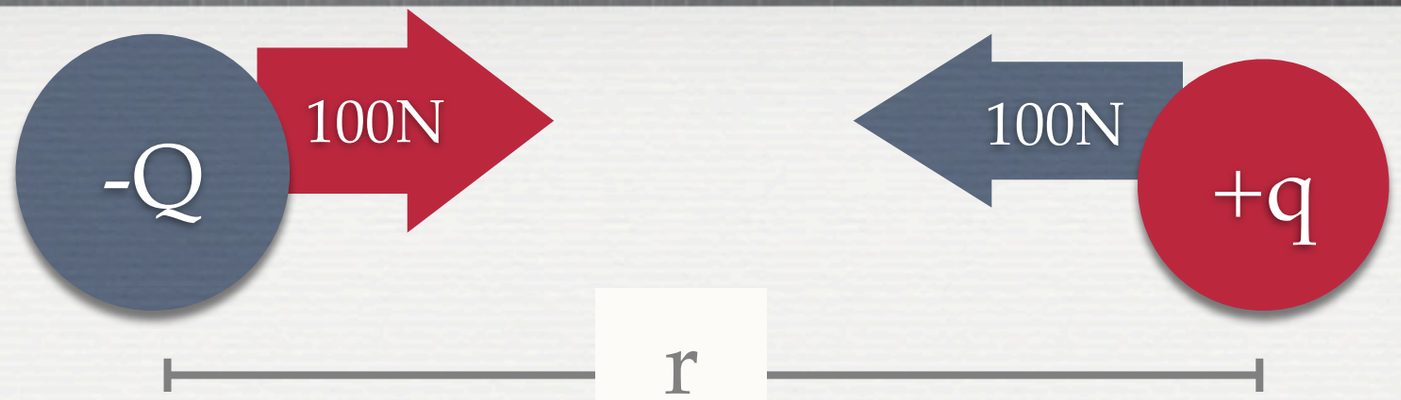


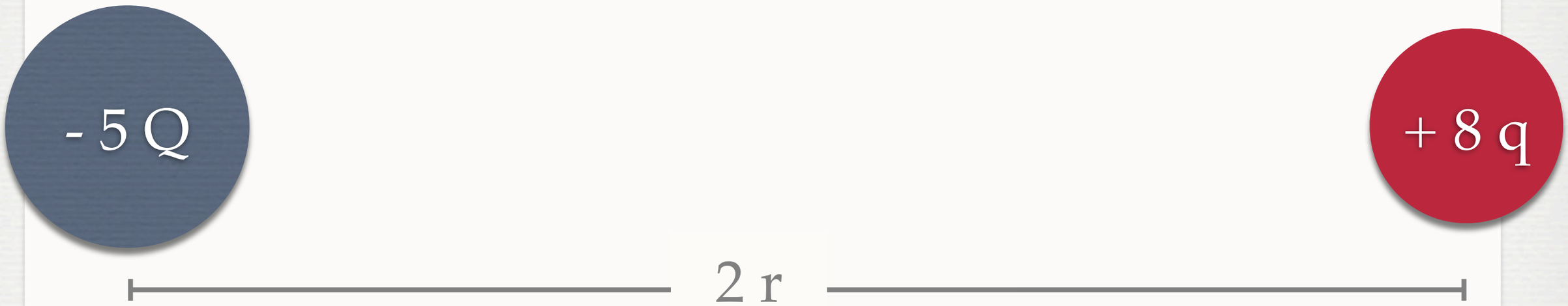


- What is the force on the left charge?

400N

RELATIVE CHANGES

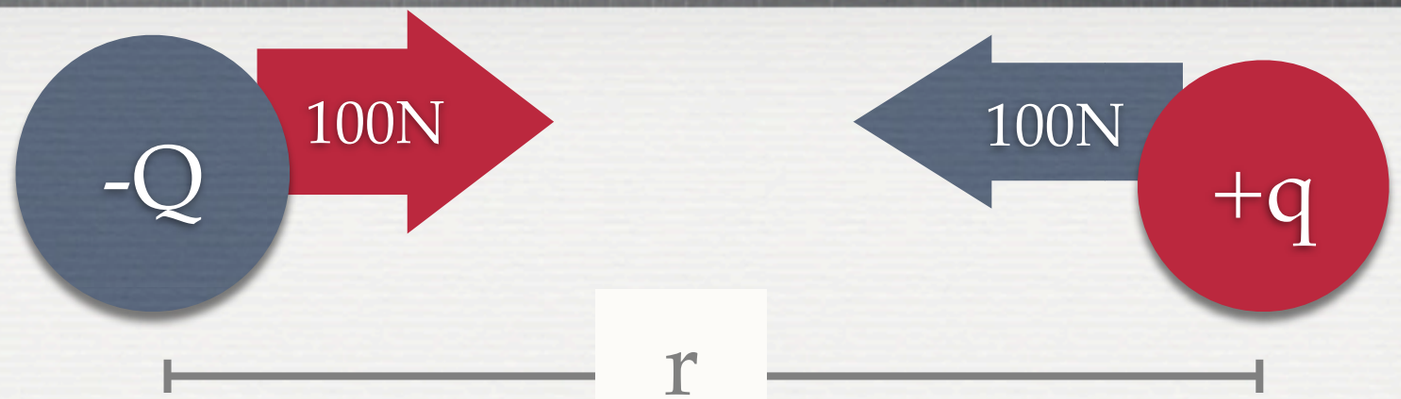


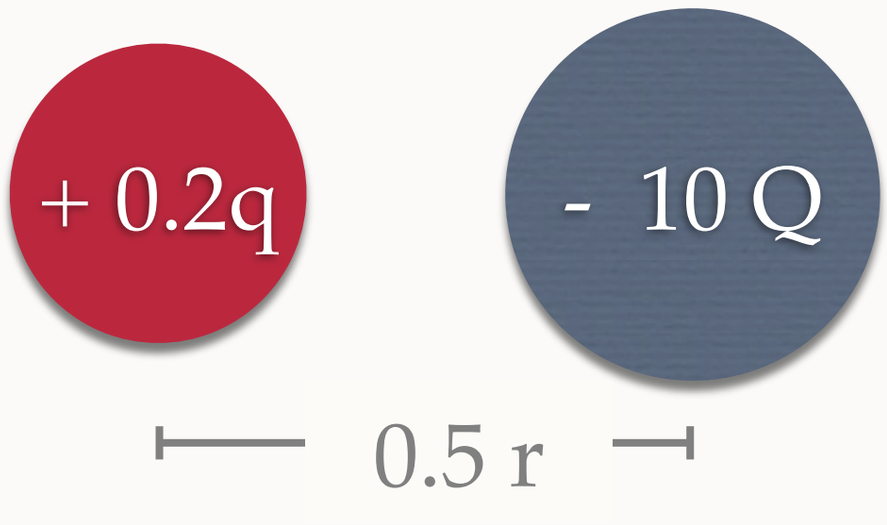


- What is the force on the left charge?

1000N

RELATIVE CHANGES

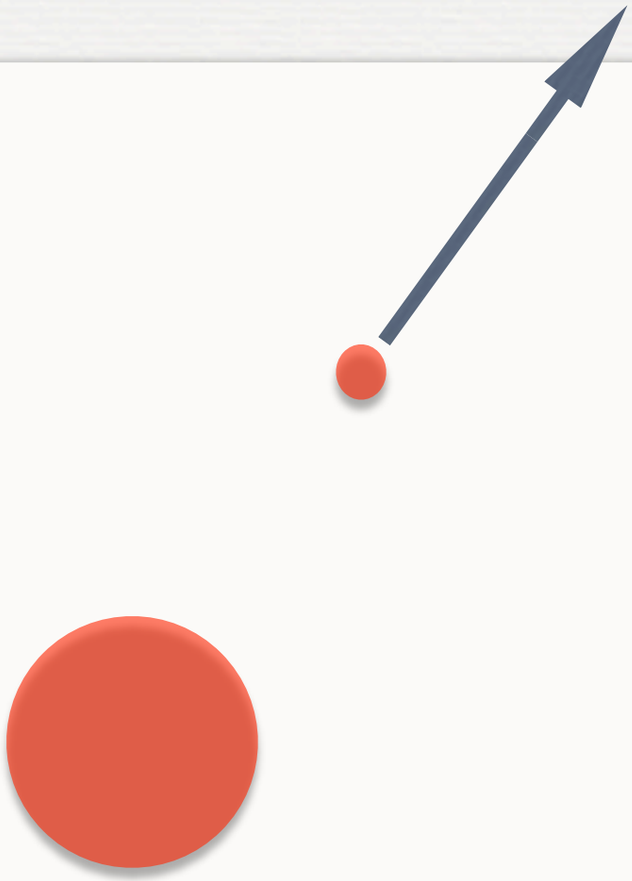




- What is the force on the left charge?

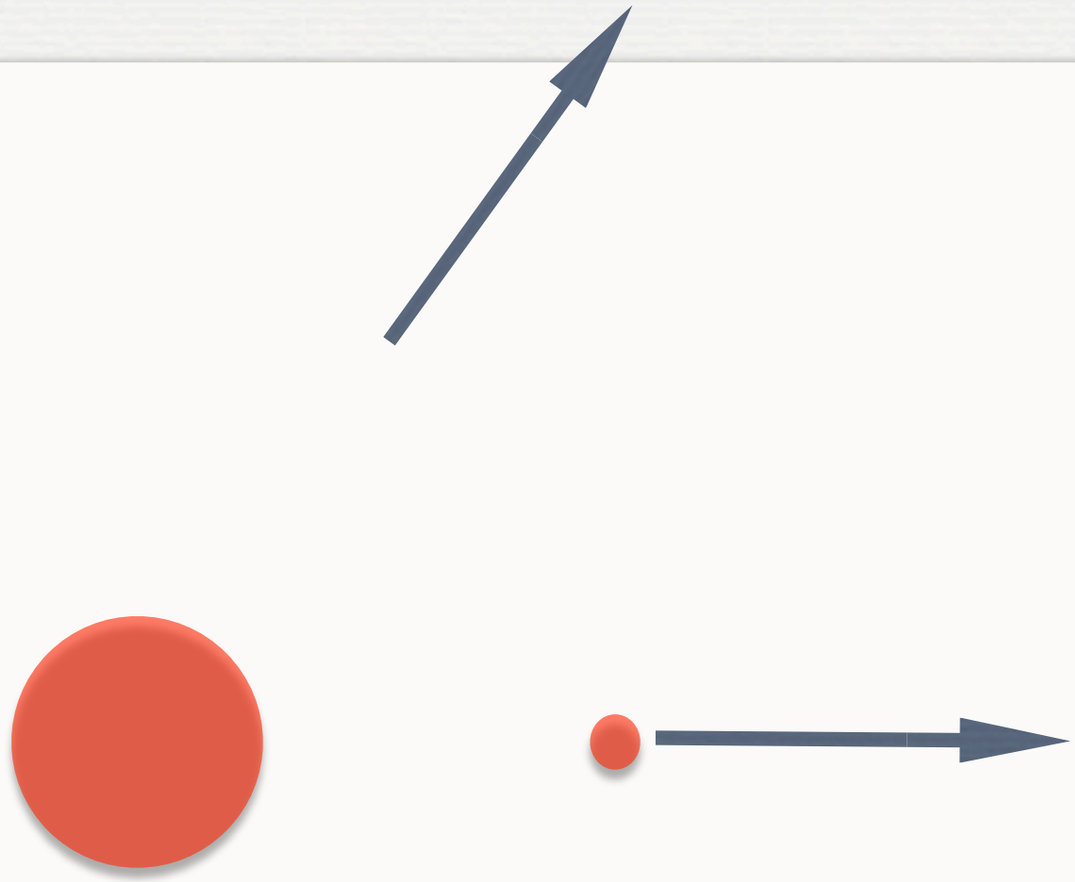
800N

ELECTRIC FIELD



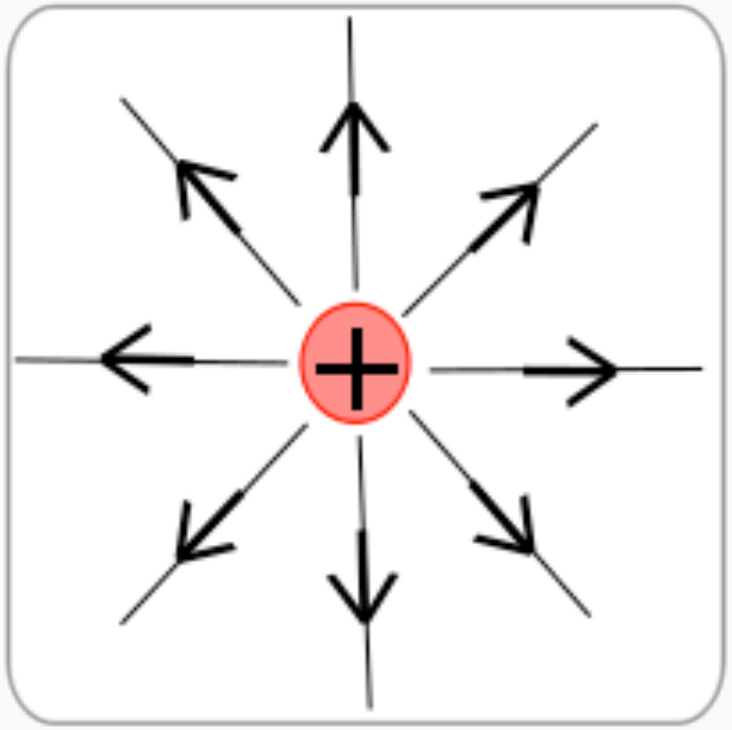
- Field Lines showing the direction of a force that WOULD exist on a positive charge.

ELECTRIC FIELD



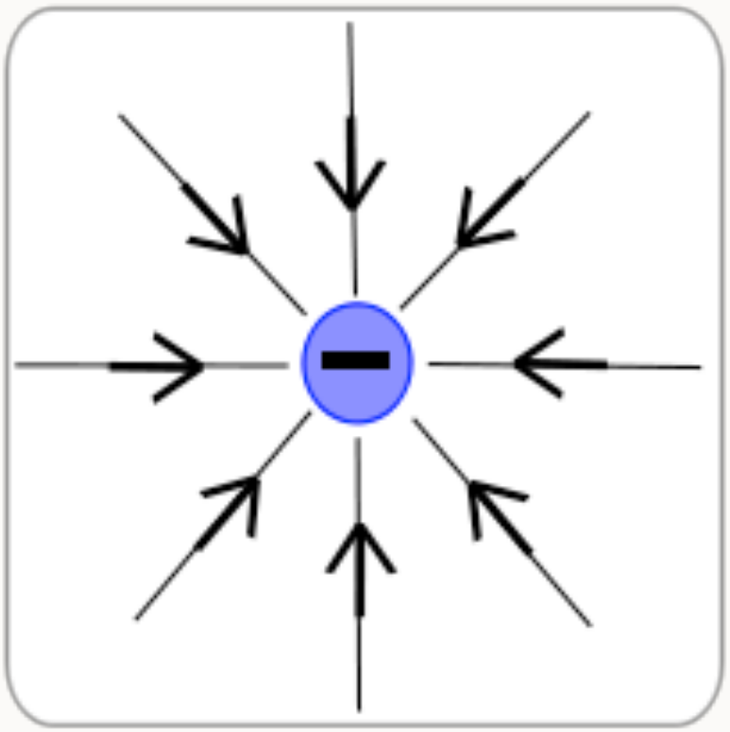
- Keep adding test charges

POSITIVE MONOPOLE



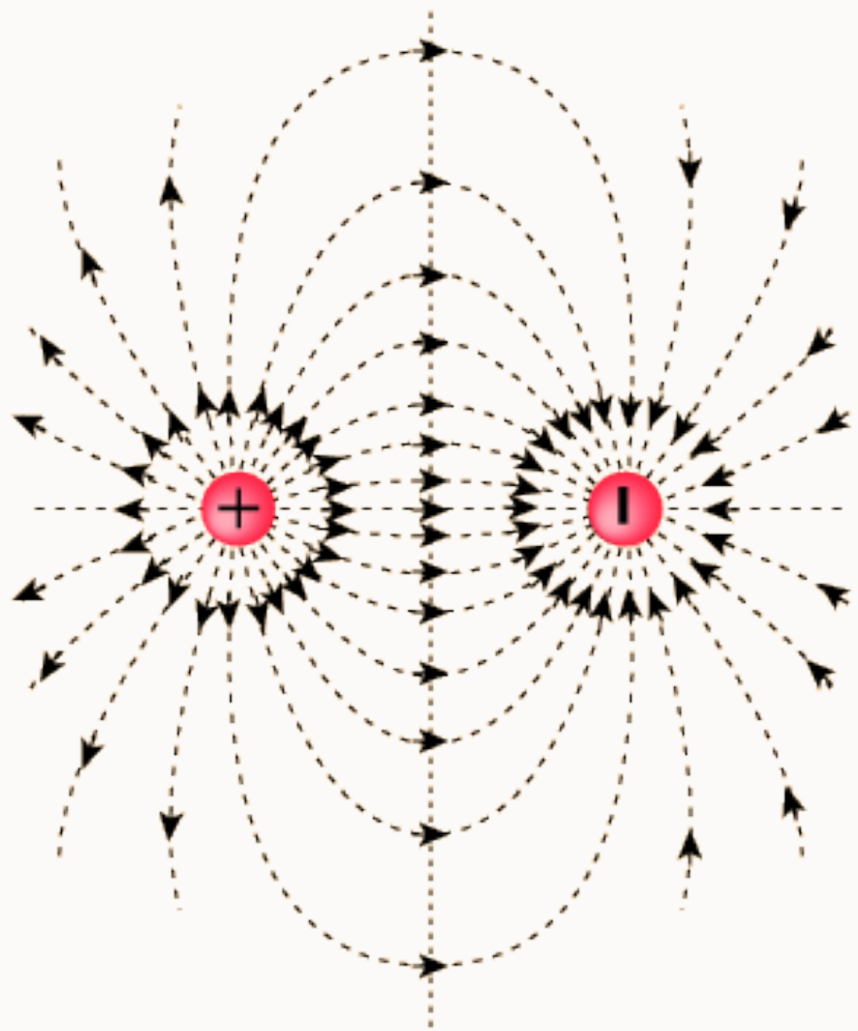
- All the lines going away from the positive charge

NEGATIVE?



- The lines would go towards the charge instead

DIPOLE



- Still, the lines go away from the positive, and towards the negative

ELECTRIC FIELD

$$E = \frac{kQ}{r^2}$$

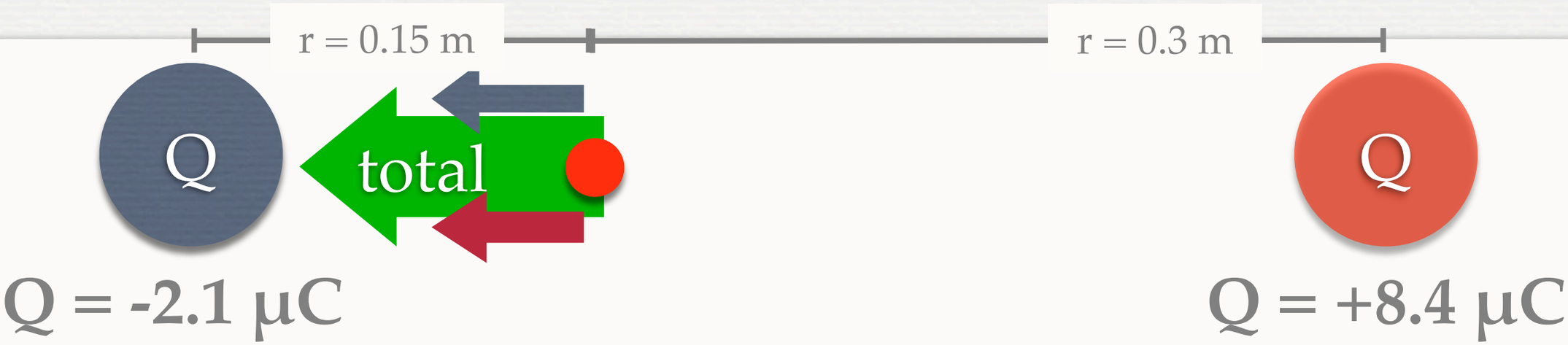
- E Electric Field
- k constant 9×10^9
- Q source charge
- r Distance from the charge

FORCE IN A FIELD

$$F = Eq$$

- The electric field shows the direction of a force that WOULD exist on a positive charge
- The actual force would be in the opposite direction for a negative charge

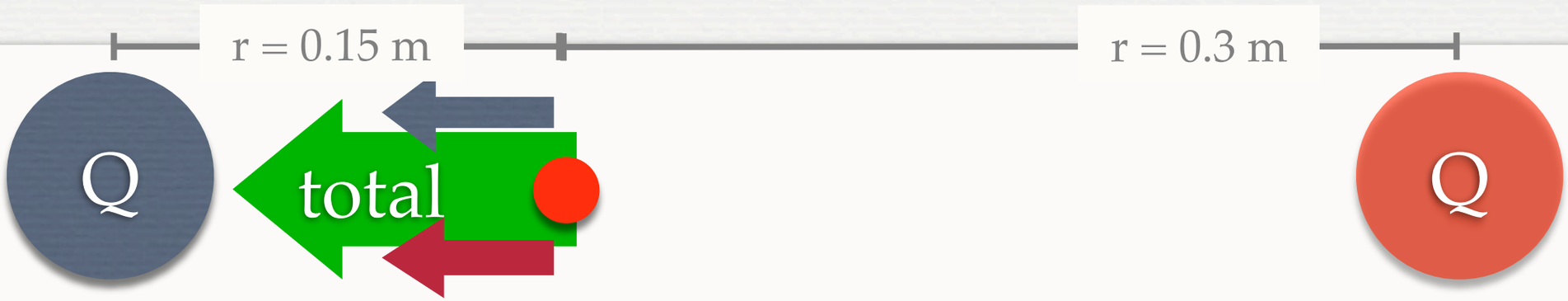
MULTIPLE CHARGES - E FIELD



Q = -2.1 μC

Q = +8.4 μC

MULTIPLE CHARGES - E FIELD



Q = -2.1 μC

Q = +8.4 μC

$$E = \frac{kQ}{r^2}$$

$$E = \frac{kQ}{r^2}$$

$$\frac{E = [(9x10^{9})(-2.1x10^{-6})]}{(0.15^{2})}$$

$$\frac{E = [(9x10^{9})(8.4x10^{-6})]}{(0.3^{2})}$$

$8.4 \times 10^{5} N/C$

$8.4 \times 10^{5} N/C$

MULTIPLE CHARGES - E FIELD

Q = -2.1 μC

Q = +8.4 μC

$-8.4 \times 10^5 N/C$

$8.4 \times 10^5 N/C$

$E = 1.68 \times 10^6 N/C$, to the left

IF a + charge is placed at that location $F = Eq$

ALL THE EQUATIONS

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

Force (N)

Electrostatic Force

attracts or repels

ALL THE EQUATIONS

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

$$E = \frac{kQ}{r^2}$$

Electric Field (N/C)

similar to gravity (g) in a gravity problem

ALL THE EQUATIONS

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

$$E = \frac{kQ}{r^2}$$

$$V = \frac{kQ}{r}$$

Voltage (volt)
Electric Potential
similar to the height in a gravity problem

ALL THE EQUATIONS

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

$$E = \frac{kQ}{r^2}$$

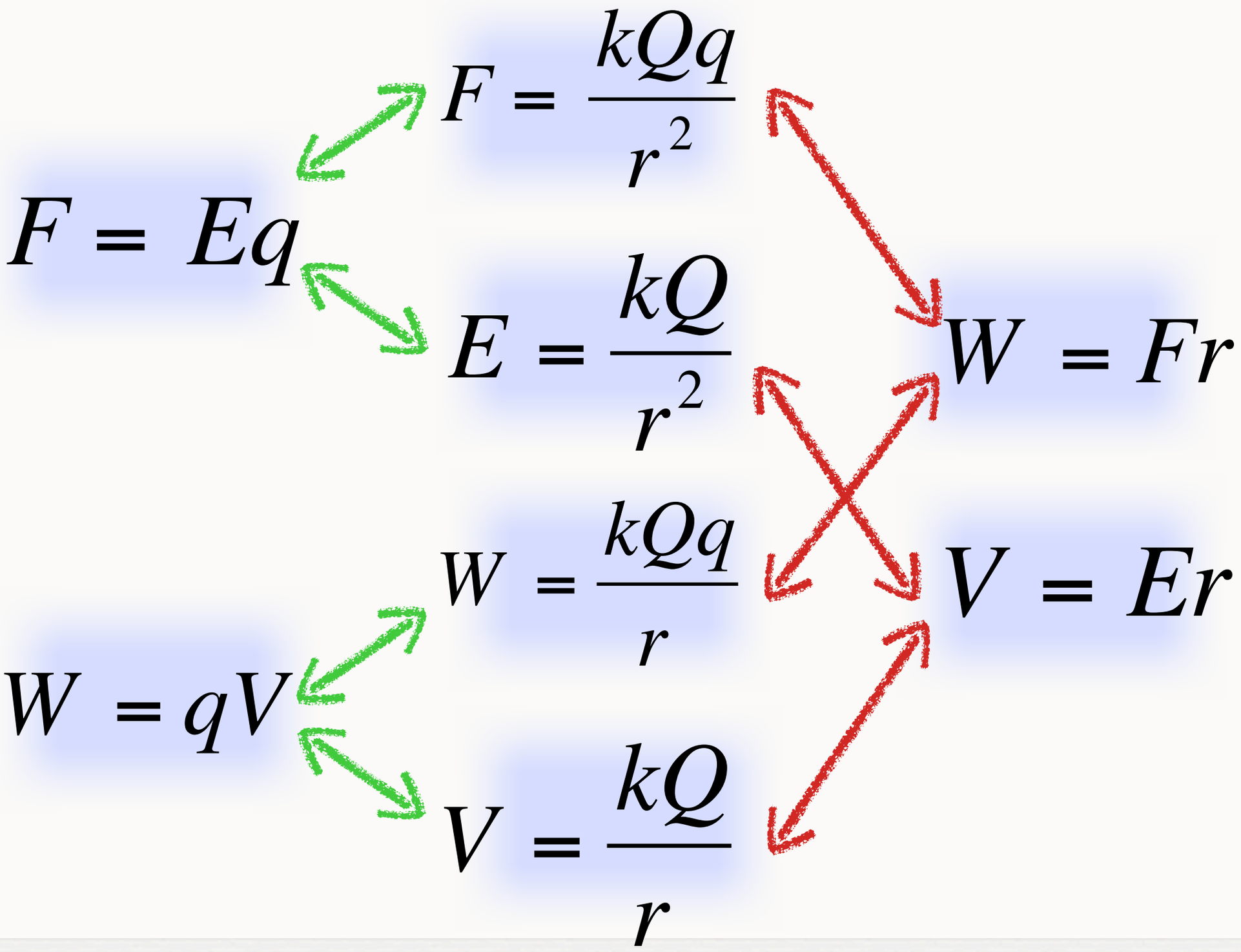
$$W = \frac{kQq}{r}$$

Work or Energy (J)

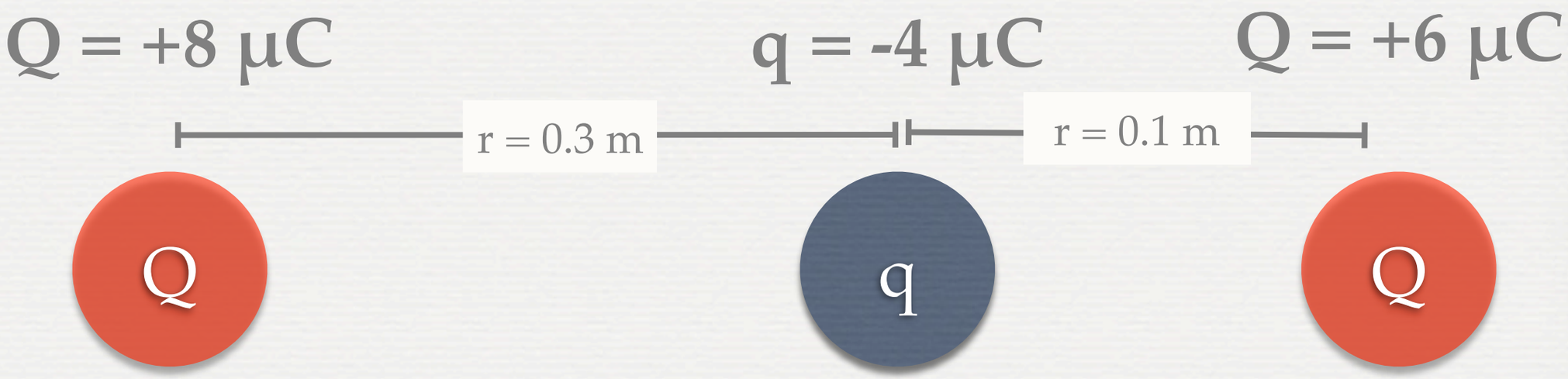
similar to PE in a gravity problem

$$V = \frac{kQ}{r}$$

ALL THE EQUATIONS



SOLVE FOR ALL VALUES

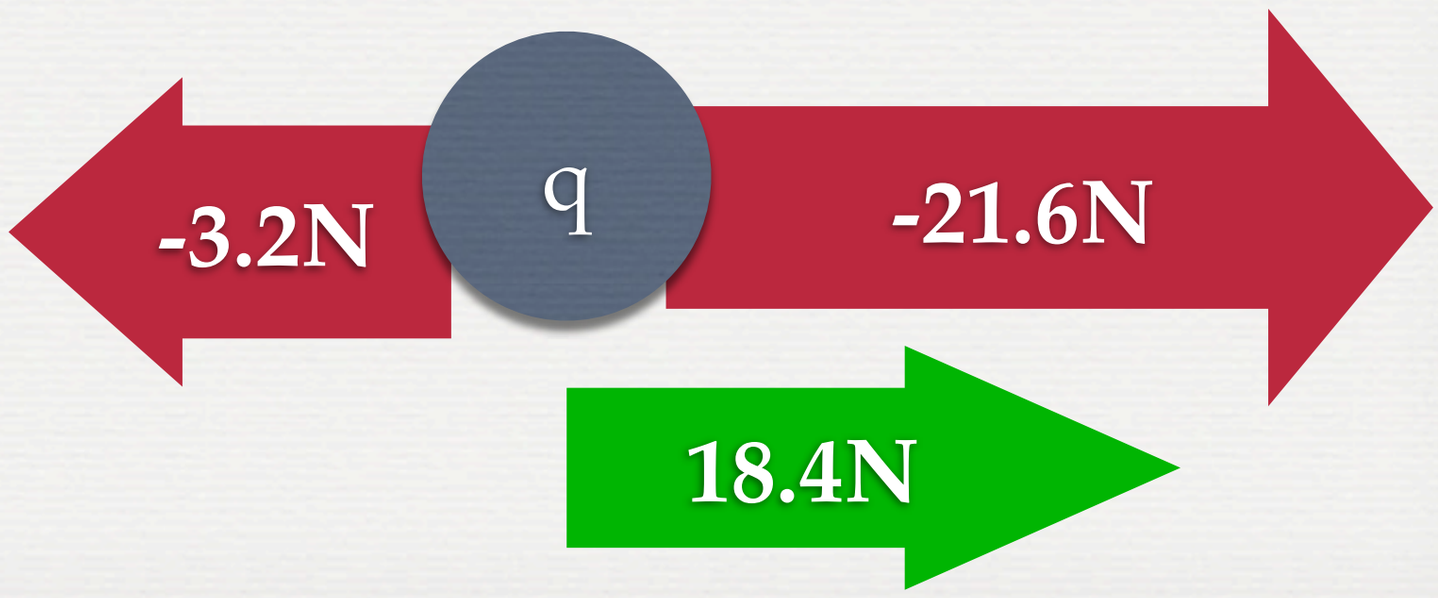


$$F = \frac{kQq}{r^2}$$

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

$$F = \frac{[(9 \times 10^{9})(8 \times 10^{-6})(-4 \times 10^{-6})]}{(0.3^{2})}$$

$$F = \frac{[(9 \times 10^{9})(6 \times 10^{-6})(-4 \times 10^{-6})]}{(0.1^{2})}$$



SOLVE FOR ALL VALUES

Q = +8 μC

Q = +6 μC

r = 0.3 m

r = 0.1 m

Q

+

Q

$$E = \frac{kQ}{r^2}$$

$$E = \frac{kQ}{r^2}$$

$$\frac{E = [(9x10^{9})(8x10^{-6})]}{(0.3\ ^{2})}$$

$$\frac{E = [(9x10^{9})(6x10^{-6})]}{(0.1\ ^{2})}$$

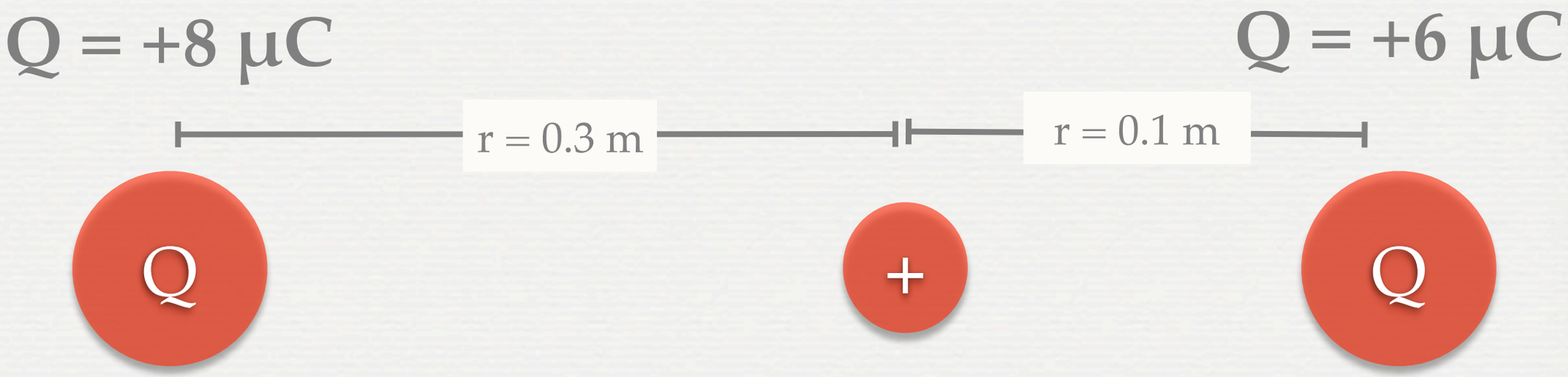
5,400,000 N/C

+

800,000 N/C

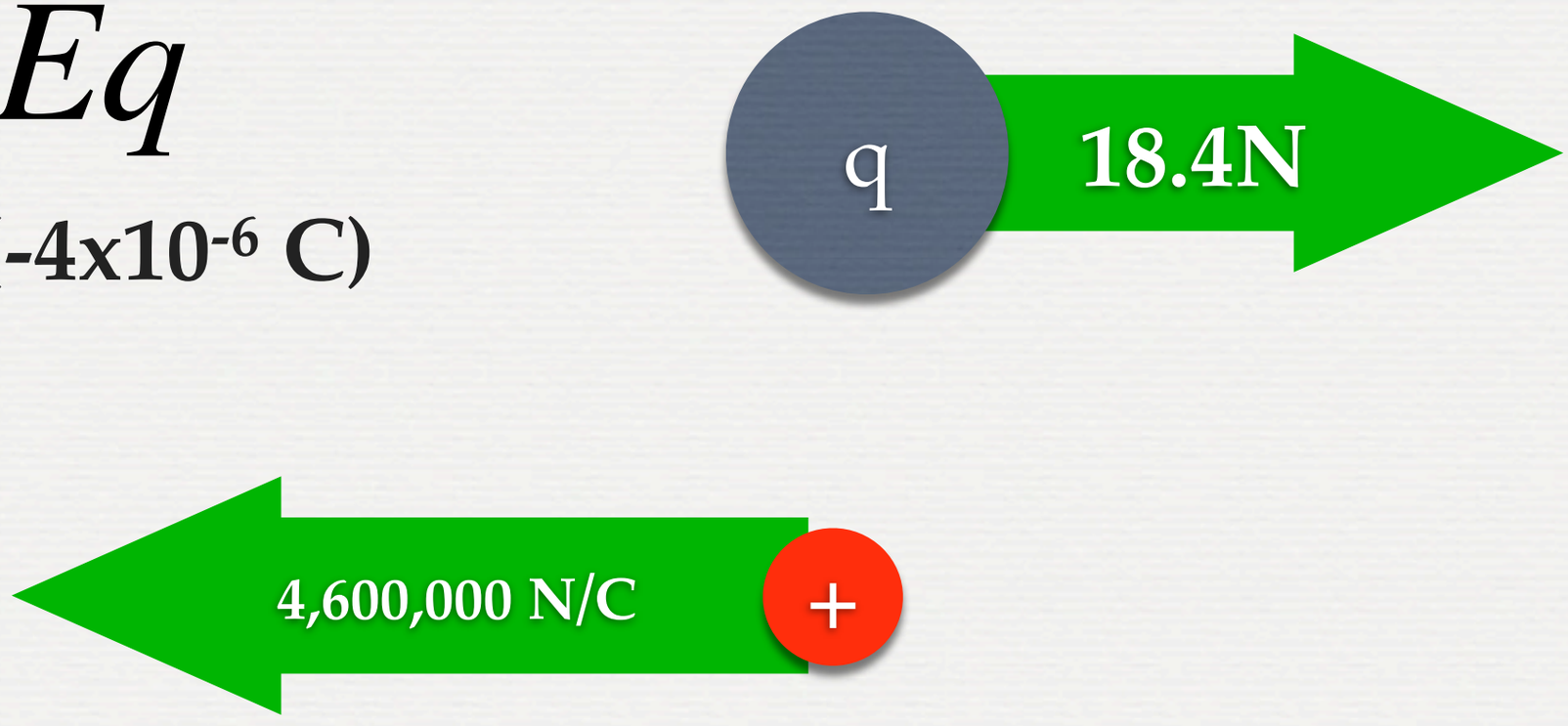
4,600,000 N/C

SOLVE FOR ALL VALUES



$$F = Eq$$

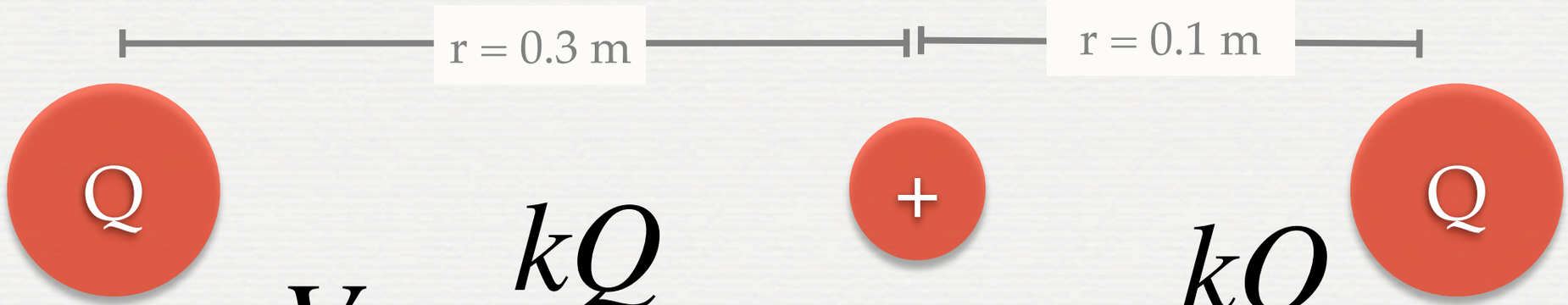
$$18.4\ N = E\ (-4x10^{-6}\ C)$$



SOLVE FOR ALL VALUES

Q = +8 μC

Q = +6 μC



$$V = \frac{kQ}{r}$$

$$V = \frac{kQ}{r}$$

$$\frac{V = [(9x10^{9})(8x10^{-6})]}{(0.3)}$$

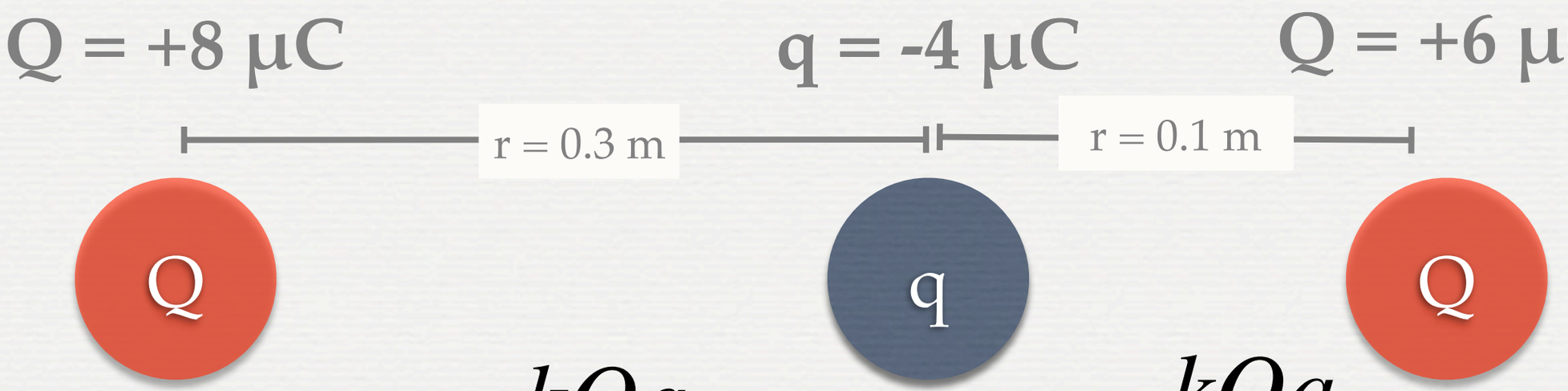
$$\frac{V = [(9x10^{9})(6x10^{-6})]}{(0.1)}$$

V = 240 kV

V = 540 kV

$$\mathbf{V_{total} = 780\ kV}$$

SOLVE FOR ALL VALUES



$$W = \frac{kQq}{r}$$

$$W = \frac{kQq}{r}$$

$$\frac{W = [(9x10^{9})(8x10^{-6})(-4x10^{-6})]}{(0.3)}$$

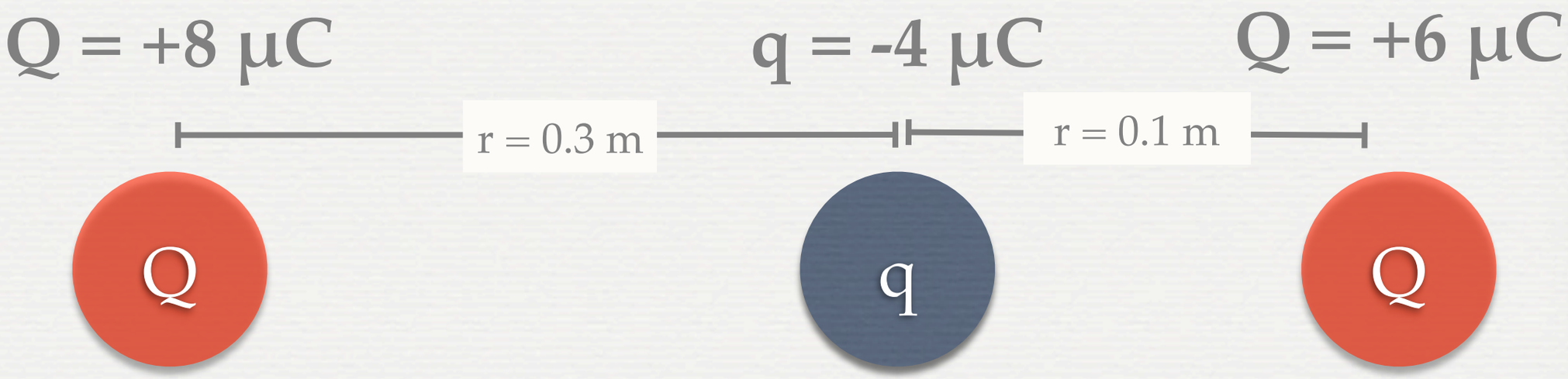
$$\frac{W = [(9x10^{9})(6x10^{-6})(-4x10^{-6})]}{(0.1)}$$

W= -0.96 J

W= -2.16 J

W_{total} = -3.12 J

SOLVE FOR ALL VALUES



$$W = qV$$

$$W = (780 \times 10^{3} V)\ (-4 \times 10^{-6}\ C)$$

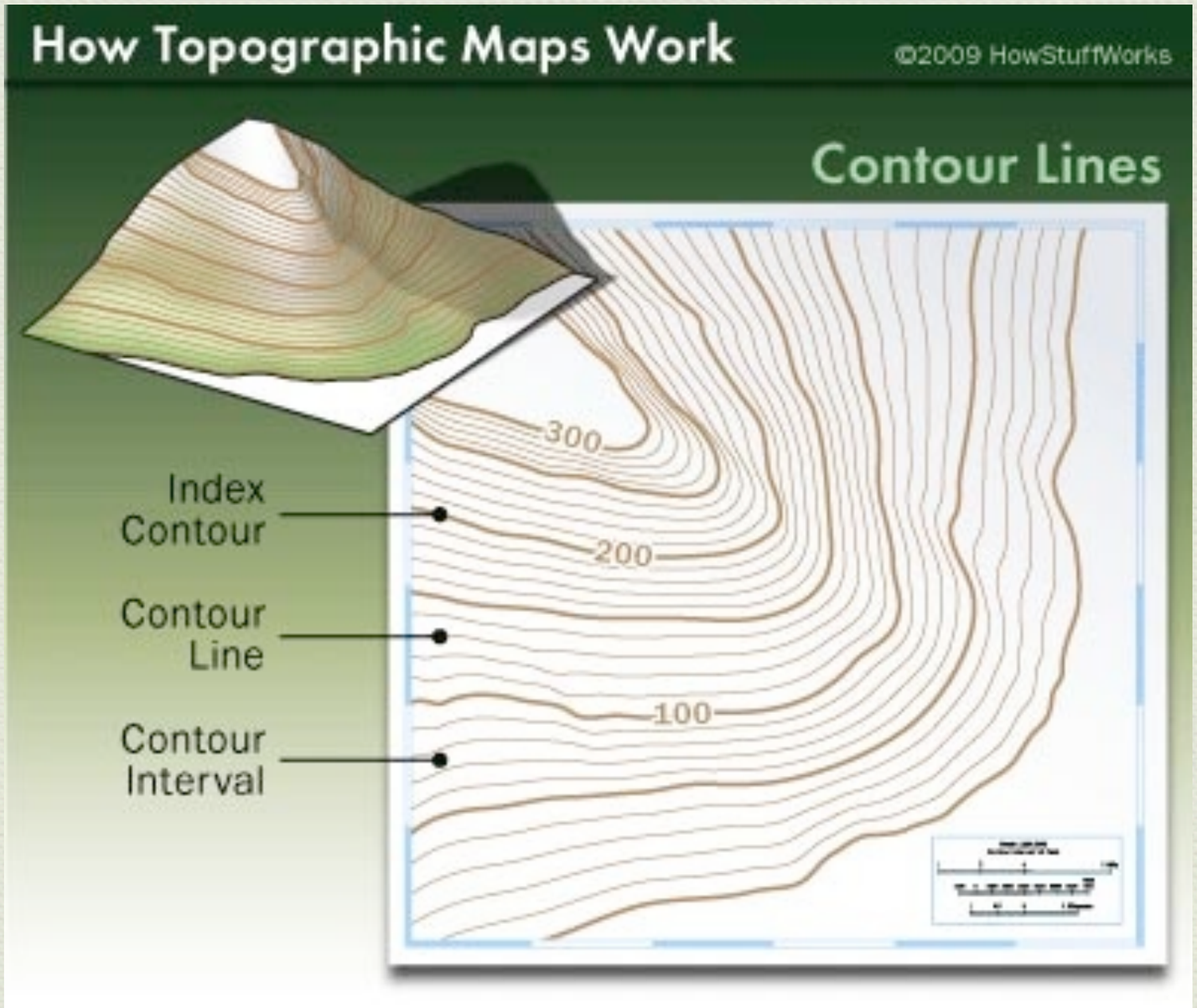
$$W = -3.12\ J$$

$$V_{total} = 780\ kV$$

Plotting an Electric Field

Like a Topographic Map

- Where do you start?
- What are all those curved lines for?



Potential Energy

gh (not yet mgh)

- 70
- 60
- 50
- 40
- 30
- 20
- 10

Force of gravity

and the path objects would follow