

Big Ideas

- Opposite charges/poles attract while like charges/poles repel
- The force between charged particles demonstrates the same relationship as the force between bodies with mass
- A force field describes the force at a location per unit mass, charge, or current
- A current flowing through a conductor produces a magnetic field
- The relative directions of current, magnetic field, and electromagnetic force can be found using the right-hand rules

1 – Static Electricity

I can describe the conservation of charge and the types of charging			
I can describe the process for how Millikan experimentally determined the charge of an electron			
I can calculate the charge on an object based on the number of electrons and protons			

2 – Electrostatic and Gravitational Force

I can use Coulomb's Law to relate electrostatic force to particle charge and separation distance			
I can use the Law of Gravitation to relate gravitation force to object mass and separation distance			
I can determine the units of Coulomb's Constant and the Gravitation Constant using unit analysis			
I can describe how the sign of the calculated electrostatic force indicates attraction or repulsion			
I can describe the impact of separation distance on electric and gravitational force			
I can discuss the impact of permittivity on Coulomb's Constant			

3 – Mapping Force Fields

I can draw gravitational fields using vectors			
I can describe the role of a test charge or test mass in representing force fields			
I can describe gravitational fields as warping spacetime			
I can draw electric fields for point charges and charged plates using vectors			
I can draw magnetic fields around north and south poles			

4 – Calculating Field Strength

I can use the law of gravitation and circular motion to describe the motion of an orbiting body			
I can calculate field strength with proper units around a single object			
I can calculate the net field strength based on two or more objects			
I can determine the location where the net field strength is zero			

5 – Magnetism and the Right Hand Rule

I can describe how permanent magnets are created by aligned magnetic domains			
I can indicate a vector that is pointing into or out of the page			
I can use the right-hand rule to draw the magnetic field around a current carrying wire			
I can use the right-hand rule to predict the forces on a current carrying wire in a magnetic field			
I can predict the trajectory of a charged particle moving through a magnetic field at different speeds			

6 – Electromagnetic Force

I can calculate electromagnetic force on a current carrying wire in a magnetic field			
I can describe and calculate the force between two parallel current carrying wires			
I can calculate the force on a charged particle in a magnetic field			

Charging and Electric Charge

Friction	Conduction	Induction
Materials transfer electrons through rubbing	Charges spread out when objects are in contact	Charged object rearrange charges in nearby object

Millikan's Oil Drop Experiment

- Used balanced forces to measure charges of small oil droplets
- Charge magnitudes repeated in regular intervals
- Charge of an electron/proton is the interval measured

Charge magnitude of 1 electron or proton	$1.60 \times 10^{-19} \text{ C}$
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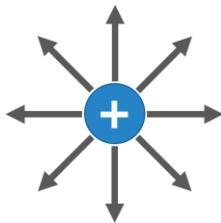
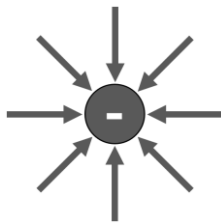
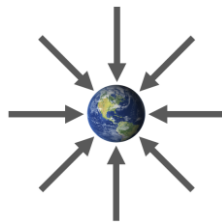
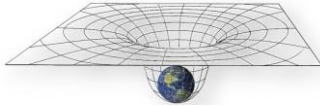
Electrostatic Force

	Variable Symbol	Description	Unit
$F = k \frac{q_1 q_2}{r^2}$ $k = \frac{1}{4\pi\epsilon_0}$	F	Electrostatic Force	Newton [N]
	q ₁	Object 1 Charge	Coulomb [C]
	q ₂	Object 2 Charge	Coulomb [C]
	r	Separation Distance	Meter [m]
	k	Coulomb Constant	$8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
	ε ₀	Permittivity of Free Space	$8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

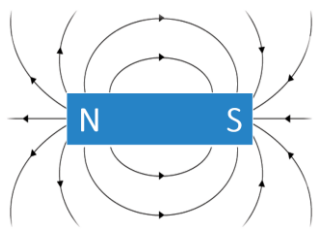

Gravitational Force

	Variable Symbol	Description	Unit
$F = G \frac{Mm}{r^2}$	F	Gravitational Force	Newton [N]
	M	Object 1 Mass	Kilogram [kg]
	m	Object 2 Mass	Kilogram [kg]
	r	Separation Distance	Meter [m]
	G	Gravitational Constant	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

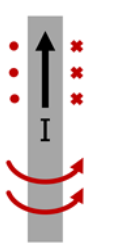
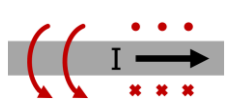
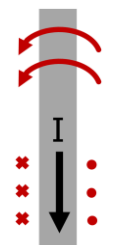
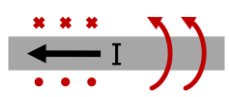
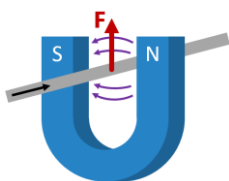
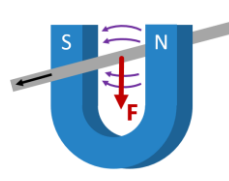
Force Fields

Electric Field			Gravitational Field				
							
Symbol	E	<i>Data Booklet Equation:</i>		Symbol	g	<i>Data Booklet Equation:</i>	
Units	F C⁻¹	$E = \frac{F}{q} \quad E = \frac{V}{d}$		Units	F kg⁻¹	$g = \frac{F}{m} \quad g = G \frac{M}{r^2}$	

Magnetic Fields

	
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Right Hand Rule

Right Hand Rule #1			Right Hand Rule #2		
Magnetic field around a current carrying wire			Electromagnetic force direction on a wire or moving particle		
Thumb	Current		Thumb	Current	
Fingers	Magnetic Field		Fingers	Magnetic Field	
			Palm	Force	
					

Electromagnetic Force

	Variable Symbol	Description	Unit
$F = BIL \sin \theta$ $F = qvB \sin \theta$ $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$	F	Magnetic Force	Newtons [N]
	B	Magnetic Field Strength	Tesla [T]
	I	Current	Ampere [A]
	L	Wire Length	Meter [m]
	θ	Angle to Field	°
	q	Particle Charge	Coulomb [C]
	v	Particle Velocity	m/s or $m s^{-1}$
	r	Separation Distance	Meter [m]
	μ_0	Permeability of free space	$4\pi \times 10^{-7} T m A^{-1}$

Charged Particles Moving through a Magnetic Field

	Magnetic Field Out of Screen	Magnetic Field Into Screen
Positive Particle		
Negative Particle		