

## Core Idea PS2

### **Motion and Stability: Forces and Interactions**

*How can one explain and predict interactions between objects and within systems of objects?*

- interaction (between any two objects)
  - gravity
  - electromagnetism
  - strong nuclear interactions
  - weak nuclear interactions
- force
- motion
- change  $\Delta$
- system(s)
- scale
- gravity
- electromagnetism
- strong nuclear interactions
- weak nuclear interactions

### PS2.A: FORCES AND MOTION

*How can one predict an object's continued motion, changes in motion, or stability?*

- interactions
- force
- change in motion
- individual force (strength and direction)
- static
- vector sum
- Newton's third law
- macroscale
- Newton's second law of motion
- $F = ma$  (total force = mass times acceleration)
- macroscopic object
- mass
- speed
- speed of light
- molecular scale
- atomic scale
- subatomic scale

An understanding of the forces between objects is important for describing how their motions change, as well as for predicting stability or instability in systems at any scale.

- momentum
- velocity
- total momentum within the system
- external force
- matter flow
- conserved quantity

*Grade Band Endpoints for PS2.A*

***By the end of grade 2.***

- object
- pull
- push
- collide (collision)
- push/pull strength and direction
- speed
- direction of motion
- start or stop motion
- sliding object
- sitting object
- slope
- friction

***By the end of grade 5.***

- object (force acts on one particular object and has both a strength and a direction)
- object at rest typically
- zero net force
  - (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)
- pattern
- observation
- measurement
  - (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)

***By the end of grade 8.***

- interacting objects
- Newton's third law
- motion of an object
- sum of the forces
- total force on the object
- mass
- shape
- orientation
- position of an object
- direction of force & motion
- use arbitrarily chosen reference frame
- use arbitrarily chosen units of size

***By the end of grade 12.***

- Newton's second law
- change in the motion of macroscopic objects
- subatomic scale
- speed
- speed of light
  - (Boundary: No details of quantum physics or relativity are included at this grade level.)
- momentum
- frame of reference
- mass
- velocity
- system
- total momentum
- conserved quantity

**PS2.B: TYPES OF INTERACTIONS**

*What underlying forces explain the variety of interactions observed?*

- force
- types of interactions
  - gravity
  - electromagnetism
  - strong nuclear interaction
  - weak nuclear interaction
- collision
- motion

- change  $\Delta$
- electromagnetic
- substructure
- electric charge(s)
- friction forces
- gravitational
- electric force
- magnetic force
- force field
- energy
- space
- field (can be mapped by their effect on a test object (mass, charge, or magnet, respectively))
- mass
- gravitational field
- human-scale objects
- Newton's law of universal gravitation
- gravitational force
- gravitational interaction
- evolution
- large-scale structures (e.g., the solar system, galaxies)
- universe
- patterns of motion
- electric force
- magnetic force
- electromagnetic interaction
- forces (attractive or repulsive)
- relative sign of the electric charge
- direction of current flow
- orientation of magnets
- forces' magnitude
- magnitude of the charges
- magnitude currents
- magnitude of magnetic strength
- distance
- interacting object
- electrical charge
- magnetization
- electric or magnetic fields
- electric charge (attraction and repulsion)
- atomic scale
- structure, properties, and transformations of matter
- contact force(s)

- Coulomb's law
- electrostatic forces (relating to stationary electric charges or fields) between distant objects
- strong nuclear interaction
- weak nuclear interaction
- atomic nuclei
- nuclear sizes
- nuclear stability
- nuclear rates of radioactive decay

*Grade Band Endpoints for PS2.B*

***By the end of grade 2.***

- object
- touch
- collide (collision)
- push
- change ( $\Delta$ ) motion or shape

***By the end of grade 5.***

- object
- contact
- exerted force (friction, elastic pushes and pulls)
- electric, magnetic, and gravitational forces
- magnets (push or pull at a distance)
- size (of the forces)
- properties of the objects
- forces between two magnets (depend on their orientation relative to each other)
- gravitational force of Earth

***By the end of grade 8.***

- electric and magnetic (electromagnetic) force(s)
- attractive or repulsive force
- magnitude (of a charge, current, or magnetic strength)
- distance (between the interacting objects)
- gravitational force (are attractive)
- long-range gravitational interaction(s)
- evolution
- large-scale systems in space (galaxies or the solar system, and patterns of motion within those structures)

- forces that act at a distance (gravitational, electric, and magnetic)
- force fields (that extend through space)

***By the end of grade 12.***

- Newton's law of universal gravitation
- Coulomb's law
- mathematical model
- gravitational force
- electrostatic forces
- force at a distance
- force fields (permeating space)
- transfer energy through space
- magnet
- changing electric fields
- magnetic fields
- electric charges
- changing magnetic fields
- electric fields
- attraction
- repulsion
- electric charge(s)
- atomic scale
- matter structure
- matter properties
- matter transformation(s)
- contact force(s)
- strong and weak nuclear interactions (important inside atomic nuclei)
- nuclear isotope(s)
- stable
- decay
- unstable

**PS2.C: STABILITY AND INSTABILITY IN PHYSICAL SYSTEMS**

*Why are some physical systems more stable than others?*

- system
- Interaction(s)
- stability
- instability
- rate of evolution
- balance

- imbalance
- stable system
- internal force(s)
- external force(s)
- static system
- unstable system
- stable repeating cycle of changes
- regular patterns of change
- prediction
- flows or processes
- rates
- stability
- instability
- balance of competing effects
- steady state
- complex system
- feedback mechanism(s)
- change in condition(s)
- range of stability
- homeostasis
- energy input(s)
- unstable state
- stable configuration
- temperature
- systems may appear static or dynamic
- conditions and properties of the objects within a system
- the rates of energy transfer
- heat conduction
- the diffusion of particles in a fluid
- colliding molecules
- average temperature
- average motion
- rates of chemical change
- trajectories molecules

*Grade Band Endpoints for PS2.C*

***By the end of grade 2.***

- object
- still
- movement
- push(es)

- pull(s)
- slope

***By the end of grade 5.***

- system
- change  $\Delta$
- movement
- direction
- cyclical pattern(s)
- force(s)
- system's patterns of change
- change (occurring at opposite but equal rates)
- change (fast or slow)
- heat conduction rates

***By the end of grade 8.***

- stable system
- system state
- system (can be static but unstable)
- system (can be changing but have a stable repeating cycle of changes)
- change (regular patterns)
- prediction(s)
- feedback mechanism(s)
- unstable state
- stable configuration

***By the end of grade 12.***

- systems (can change in predictable ways)
- force(s)
- transformation(s)
- cycle(s)
- system (has a great number of component pieces)
- colliding molecule
- properties of material or matter (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules).
- systems (evolve in unpredictable ways when the outcome depends sensitively on the starting condition and the starting condition cannot be specified precisely enough to distinguish between different possible outcomes)