Core Idea PS3

Energy

How is energy transferred and conserved?

- interaction
- object
- explain
- predict
- concept: the transfer of energy from one object or system of objects to another
- total energy
- defined system
- changes only by the transfer of energy into or out of the system.

PS3.A: DEFINITIONS OF ENERGY

What is energy?

- defined quantity
- energy
- conservation of (a system’s total) energy
- subsystems
- energy transfer
- macroscopic scale
  - energy manifestations (matter (energy=matter x speed of light^2), motion, light, sound, electrical and magnetic fields, and thermal energy)
- units for energy
- microscopic scale
  - energy manifestations (motions of particles, stored in force fields -- electric, magnetic, gravitational)
- particle(s) (atomic and subatomic)
- electromagnetic radiation (light, radio waves)
- space (void of matter)
- motion
- kinetic energy
- reference frame
- proportional
- mass
- matter
- temperature
- absolute zero
- thermal energy
- vibration(s)
• solid
• molecules
• free motion
• gas
• collision
• interactions/action/force at a distance
• sound wave
• pattern
• electric field
• magnetic field
• magnet(s)
• equilibrium position(s)
• atomic nuclei
• molecule
• chemical bond
• metal(s)
• stored energy
• potential energy
• spatial configuration
• gravitational field
• gravitational potential energy
• falling objects
• pendulum
• friction
• electromagnetic radiation (such as light and X-rays)
  o wave of changing electric and magnetic fields
• subatomic scale (i.e., in quantum theory)
• photoelectric effect
• photon(s)
• sun
• earth
• forms of energy (thermal energy, mechanical energy, and chemical energy)
• atomic scale
• radiation.

Grade Band Endpoints for PS3.A

By the end of grade 2. [Intentionally left blank.]
By the end of grade 5.

- faster
- object
- move(ing)
- energy (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)
- sound
- light
- electric currents

At the macroscopic scale, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy.

By the end of grade 8.

- motion energy
- kinetic energy
- proportional
- mass
- system
- object(s)
- potential energy
- relative position
- energy
- store/d/age
- gravitational interaction
- fall(s/ing)
- electric field
- charged particle(s)
- magnetic field(s)
- magnet
- relative motion
- stored energy
- chemical reaction(s)
- heat
- thermal energy (the motion of atoms or molecules within a substance)
- energy transfer (by convection, conduction, and radiation (particularly infrared and light))
- science
• temperature
• measure
• average kinetic energy
• particles of matter
• total energy of a system
• matter state
• matter amount
• absence of matter

By the end of grade 12.

• energy
• quantitative property
• system
• motion
• interaction(s)
• matter
• radiation
• single quantity
• Conservation of energy (a system’s total energy energy is conserved)
• energy transformation
• energy on a macroscopic scale
  o motion
  o sound
  o light
  o thermal energy
• mechanical energy (motion + stored energy in an operating machine)
• chemical energy (energy that can be released or stored in chemical processes)
• electrical energy (energy stored in a battery or energy transmitted by electric currents)
• units of energy
• microscopic scale
• can be modeled as either
  o motions of particles
  o energy stored in fields (which mediate interactions between particles).
    - Like radiation

PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER

What is meant by conservation of energy?
How is energy transferred between objects or systems?

• change Δ
• energy
• system
• total energy
• conservation of energy
• energy transfer(s)
• mathematical expressions (which quantify changes in the forms of energy within a system and transfers of energy into or out of the system)
• motion energy (change in shape or temperature of objects)
• macroscopic objects
• collisions
• sliding contact
• energy transfers to the surrounding air (sound or heat)
• energy transfers to molecules (collisions, chemical processes, which increase or decrease the total amount of stored energy within a system of atoms)
• $\Delta$ in stored energy
• kinetic energy
• electric current
• heating
• heat transfer
• temperature
• cooling
• conduction
• solid(s)
• liquid(s)
• gas
• convection
• radiation (emitted or absorbed by matter)
• particle in matter
• light
• infrared radiation
• thermal motion of particles in the matter
• wavelength (ultraviolet, X-ray)
• ionization (of atoms or molecules)
• electron
• uncontrolled system(s)
• stable states
• decay
• radioactive isotopes
Grade-Level Endpoints for PS3.B

By the end of grade 2.

- sunlight
- warm
- earth
- surface

By the end of grade 5.

- energy
- object
- sound
- light
- heat
- collide
- energy transfer
- collision
- air
- heat
- light
- energy radiated (as from the sun)
- warm
- Earth
- land
- water
- plant growth
- electric current
- motion
- sound

By the end of grade 8.

- motion energy
- object Δ
- energy
- friction
- thermal energy
- cool
- chemical energy (e.g., burning fuel)
- electrical energy (e.g., an electric motor and a battery)
- temperature
• matter
• nature of the matter
• conduction
• convection
• radiation

By the end of grade 12.

• conservation of energy
• total change of energy
• energy transferred
• energy
• system(s)
• mathematical expressions
• quantify
• stored energy (e.g., relative positions of charged particles, compression of a spring)
• kinetic energy
• mass
• speed
• uncontrolled system(s)
• degrade
• long-lived radioactive isotopes

PS3.C RELATIONSHIP BETWEEN ENERGY AND FORCES

How are forces related to energy?

• object
• interact
• force
• transfer energy
• force fields (gravitational, electric, or magnetic)
• contact forces
• colliding objects
• microscopic level
• electromagnetic force fields
• relative position
• pattern(s) of motion
• force (at each instant)
• force (in terms of transformation of energy between the motion and one or more forms of stored energy)
• elastic collision(s)
• macroscopic scale
• conservation of energy
• microscopic forces

Grade Band Endpoints for PS3.C

By the end of grade 2.

• push
• pull
• fast
• speed
• collision
• $\Delta$ in shape

By the end of grade 5.

• object
• collide
• contact force
• transfer energy
• change in an objects’ motion
• magnet
• magnetizable material

By the end of grade 8.

• object
• interaction
• force
• energy
• Earth-object system
• gravitational field energy
• gravitational force
• magnetic or electrically charged objects
• transfer energy
• interacting objects.

By the end of grade 12.

• force field(s) (gravitational, electric, and magnetic)
• energy
• space
• $\Delta$ in relative position
How do food and fuel provide energy?
If energy is conserved, why do people say it is produced or used?

- “producing” energy
- “using” energy
- electricity
- movement
- heat
- objects
- light
- energy
- stored energy
- convenient energy
- resource
- system
- environment
- carbon-based molecules
- photosynthesis
- chemical reaction
- molecule
- oxygen
- electric power generation
- fossil fuels (i.e., coal, oil, and natural gas)
- nuclear fission
- renewable resources (e.g., solar, wind, tidal, geothermal, and hydro power)
- transportation
- alternative fuel (e.g., hydrogen, biofuel)
- economic, social, and environmental costs
- benefits (short and long term)
- technological advances
- regulatory
- energy storage
- system
- friction
- heat energy transfer
- efficiency
- waste materials
- unintended impacts
- environmental impacts
Grade Band Endpoints for PS3.D

By the end of grade 2.

- object
- rub
- friction
- warm

By the end of grade 5.

- produce energy
- conversion
- stored energy
- electricity
- fuel
- “use” energy (e.g., to move around)
- energy transfer to
- heat
- environment
- burn
- fuel
- sun
- chemical process
- plant (Boundary: The fact that plants capture energy from sunlight is introduced at this grade level, but details of photosynthesis are not.)
- concentrate
- battery
- physically transportable energy
- energy storage devices

By the end of grade 8.

- chemical reaction
- plant
- produce
- complex
- food molecules (sugars)
- energy input (i.e., from sunlight)
- carbon dioxide
- water
- carbon-based organic molecules
- oxygen
• (Boundary: Further details of the photosynthesis process are not taught at
this grade level.)
• cellular digestion
• chemical reaction
• machines
• aerodynamic design
• heat

By the end of grade 12.

• nuclear fusion
• sun
• energy
• radiation
• solar energy
• complex chemical process
• photosynthesis
• solar cell
• electrical energy.
• physical process
• chemical process
• living organism
• cell
• transport of energy
• transfer (release or uptake) of energy
• electricity generation
• electricity transportation
• economic, social, and environmental costs
• economic, social, and environmental benefits
• short and long term costs/benefits
• energy conversion to less useful forms—such as, thermal energy in the
surrounding environment
• machines
• efficiency
• waste heat
• environmental impacts