Energy Production IB Physics Content Guide

Big Ideas

- Most energy sources can be traced back the sun, our ultimate primary source
- No energy source can be converted to electricity with 100% efficiency
- All energy sources have advantages and drawbacks and it important to understand the complete picture
- Every object with a temperature above 0 K emits thermal radiation
- Radiation intensity is related to separation distance by the inverse square law (similar to force fields)
- The Earth's climate relies on a delicate thermal energy balance where total energy in equals total energy out

Content Objectives

1 – Energy Sources Overview

I can list the top 6 most common sources in the global energy supply and general % of total			
I can distinguish between primary and secondary energy sources			
I can define power as a rate of energy usage in terms of watts			
I can calculate the efficiency as the percentage of useful energy of the total			
I can interpret energy flow from a Sankey Diagram			
I can define specific energy and energy density with proper units			
I can use specific energy to calculate the amount of fuel needed for a given amount of power			

2– Nuclear Power

I can describe the chain reaction that occurs to support a self-sustaining fission reactor			
I can describe the concentration of U-235 as a sample is enriched into fuel-grade uranium			
I can outline the process of enriching uranium			
I can explain how a nuclear reactor transforms the energy of a fission reaction into electricity			
I can describe the role of the moderator and control rods in a nuclear reactor			
I can discuss the challenges of disposing of nuclear waste			

3 – The Renewables

I can list examples of energy sources that are considered renewable			
I can list examples of energy sources that are known carbon dioxide emitters			
I can calculate the power produced by a wind turbine			
I can compare the different styles of solar power and what each is used for			
I can calculate the power from a solar panel from the panel area and solar intensity			
I can describe the factors that affect the solar intensity in different locations on Earth			
I can outline the operation of a hydropower generator			
I can explain how a hydropower plant can incorporate pumped storage to store energy			
I can list challenges that are facing a future of renewable energy			

4 – Thermal Energy Transfer

I can provide examples of conduction, convection, and radiation			
I can define black-body radiation in terms of absorption and emission of light			
I can describe an object based on its emissivity			
I can calculate the power emitted by a black body radiation using the Stefan-Boltzmann Law			
I can describe the shape of the emission spectra in terms of radiation wavelength			
I can mathematically relate peak wavelength and temperature using Wien's displacement law			

5 – Radiation from the Sun

I can define intensity with proper units			
I can describe how intensity changes according to the surface area of a sphere			
I can derive the Solar Constant from the sun's power and distance from earth			
I can calculate the average solar intensity on earth from the solar constant and earth's radius			
I can compare the properties of albedo and emissivity			
I can list the gases that have the largest impact on the greenhouse effect			

6 – Climate Change

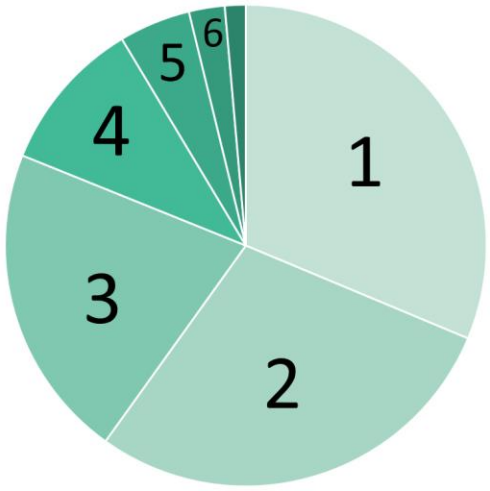
I can describe the greenhouse effect as absorption and re-emission of thermal energy			
I can describe the concept of thermal equilibrium and how it pertains to earth			
I can recognize trends in the climate model based on different factors			
I can describe the long term and seasonal trends in the carbon dioxide concentration			
I can list examples of positive and negative feedback loops in terms of the climate discussion			
I can engage in an evidence-based conversation about climate change			

Energy Production

Shelving Guide

Global Energy Usage

Rank	Energy Source	%
1	Oil	31%
2	Coal	27%
3	Natural Gas	23%
4	Biomass	9%
5	Nuclear	5%
6	Hydropower	2.5%

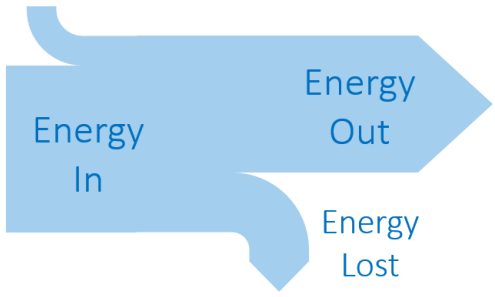


Efficiency

$$Efficiency = \frac{useful\ work\ out}{total\ work\ in} = \frac{useful\ power\ out}{total\ power\ in}$$

Sankey Diagram Rules:

Width of the arrow proportional to the amount of energy



Energy Density

	Definition	Units
Specific Energy	Energy transferred per unit mass	$J\ kg^{-1}$
Energy Density	Energy transferred per unit volume	$J\ m^{-3}$

Primary and Secondary Sources

Primary Energy Sources	Secondary Energy Sources
Energy sources found in the natural environment (fossil fuels, solar, wind, nuclear, hydro, etc.)	Useful transformations of the primary sources (electricity, pumped storage for hydro, etc.)

Nuclear Power

	Describe	Examples	Challenges
Fission	Lighter elements are created by splitting heavier elements	Nuclear Power Nuclear Weapons	Proper amounts of fissionable elements required to maintain chain reaction
Fusion	Heavier elements are created by combining lighter elements	The Sun/Stars	Requires high heat and high pressure

	% of U-235
Uranium Ore	0.7%
Fuel-Grade	3.5%
Weapons-Grade	90%

Why is the concentration of U-235 important?

Only U-235 can undergo a fission chain reaction

What is done with the nuclear waste?

Stored on-site in spent fuel pools and/or concrete dry cask storage

Moderator	Control Rods
Slows down neutrons to be absorbed by U-235 Made from Water or Graphite (carbon)	Absorbs neutrons to limit number of chain reactions Made from Boron

Renewable Energy

	Variable Symbol	Unit
Power	P	W
Cross-Sectional Area	A	m^2
Air Density	ρ	$kg\ m^{-3}$
Air Speed	v	$m\ s^{-1}$

Data Booklet Equations:

$$\text{Power} = \frac{1}{2}A\rho v^3$$

$$A = \pi r^2$$

Photovoltaic Cells	Solar Concentrator	Solar Heating Panel
Converts solar energy directly into electricity. Useful in solar panels on top of building or solar farms connected to the energy grid	Mirrors focus sunlight onto a central tower. The high thermal energy is converted to steam and runs turbines to produce electricity	Sun's radiation is absorbed by black pipes that transfer thermal energy to the water flowing through them. Replaces hot water heater.

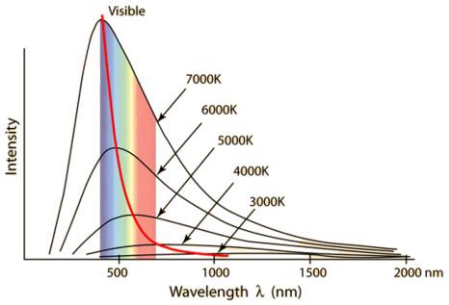
	Biomass	Coal	Geothermal	Hydropower	Natural Gas	Nuclear	Petroleum	Solar	Wind
Renewable	✓		✓	✓				✓	✓
Produces CO_2	✓	✓			✓		✓		

Thermal Energy Transfer

Conduction	Convection	Radiation
Energy is transferred through molecular collisions	Energy circulates through the expansion and rising of hot fluids	Energy is transferred through electromagnetic radiation. Can travel through a vacuum

	Emissivity
Sun	~1
Earth	~0.6
Black-Body	1

Black Body Radiation
An idealized object that absorbs **all** the electromagnetic radiation the falls on it



Power Emissivity	Variable Symbol	Unit
Power	P	W
Emissivity	e	---
Surface Area	A	m^2
Temperature	T	K
Max Wavelength	λ_{max}	m

Data Booklet Equations:

$$P = e\sigma AT^4$$

$$\lambda_{max} = \frac{2.90 \times 10^{-3}}{T}$$

$$\sigma = 5.67 \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{-4}}$$

Solar Radiation and Climate Change

Intensity	Variable Symbol	Unit
Intensity	I	$W\ m^{-2}$
Power	P	W
Area	A	m^2

Data Booklet Equations:

$$I = \frac{\text{power}}{A}$$

$$A_{sphere} = 4\pi r^2$$

Greenhouse Gases
Water Vapor (H_2O)
Carbon Dioxide (CO_2)
Methane (CH_4)

Positive Feedback Loop	Negative Feedback Loop
Melting ice (decreases albedo)	Cloud formation (increases albedo)
Melting permafrost (releases methane)	Increased photosynthesis (uses CO_2)
Rising ocean temp releases methane	Climate Change leads to renewables