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| **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

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| 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 |  |  |  |

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| 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 |  |  |  |

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| 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 |  |  |  |

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| 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 |  |  |  |

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| 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 |  |  |  |

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| 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 |  |  |  |

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| **Energy Production** | Shelving Guide |

# Global Energy Usage

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

# Efficiency

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| $$Efficiency=\frac{useful work out}{total work in}=\frac{useful power out}{total power in}$$ |  |
| Sankey Diagram Rules:Width of the arrow proportional to the amount of energy |

# Energy Density

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|  | 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

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| 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

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|  | Describe | Examples | Challenges |
| Fission | Lighter elements are created by splitting heavier elements | Nuclear PowerNuclear 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 |

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|  | % of U-235 |  | Why is the concentration of U-235 important?Only U-235 can undergo a fission chain reaction |
| Uranium Ore | 0.7% |  |
| Fuel-Grade | 3.5% |  | What is done with the nuclear waste?Stored on-site in spent fuel pools and/or concrete dry cask storage |
| Weapons-Grade | 90% |  |

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

# Renewable Energy

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| --- | --- | --- | --- | --- |
|  | Variable Symbol | Unit |  | *Data Booklet Equations:* |
| Power | P | W |  | $$Power=\frac{1}{2}Aρv^{3}$$ |
| Cross-Sectional Area | A | m2 |  |
| Air Density | ρ | kg m-3 |  | $$A=πr^{2}$$ |
| Air Speed | v | m s-1 |  |

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| 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. |

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|  | Biomass | Coal | Geothermal | Hydropower | Natural Gas | Nuclear | Petroleum | Solar | Wind |
| Renewable | **✓** |  | **✓** | **✓** |  |  |  | **✓** | **✓** |
| Produces CO2 | **✓** | **✓** |  |  | **✓** |  | **✓** |  |  |

# Thermal Energy Transfer

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| 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 |

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|  | Emissivity |  | Black Body Radiation |  |
| Sun | ~1 |  | An idealized object that absorbs **all** the electromagnetic radiation the falls on it |
| Earth | ~0.6 |  |
| Black-Body | 1 |  |

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| Power Emissivity | Variable Symbol | Unit |  | *Data Booklet Equations:* |
| Power | P | W |  | $$P=eσAT^{4}$$ |
| Emissivity | e | --- |  |
| Surface Area | A | m2 |  | $$λ\_{max}=\frac{2.90×10^{-3}}{T}$$ |
| Temperature | T | K |  |
| Max Wavelength | λmax | m |  | $$σ=5.67×10^{-8} W m^{-2} K^{-4}$$ |

# Solar Radiation and Climate Change

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| Intensity | Variable Symbol | Unit |  | *Data Booklet Equations:* |
| Intensity | I | W m-2 |  | $$I=\frac{power}{A}$$ |
| Power | P | W |  |
| Area | A | m2 |  | $$A\_{sphere}=4πr^{2}$$ |

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| Greenhouse Gases |  | Positive Feedback Loop | Negative Feedback Loop |
| Water Vapor (H2O) |  | Melting ice (decreases albedo) | Cloud formation (increases albedo) |
| Carbon Dioxide (CO2) |  | Melting permafrost (releases methane) | Increased photosynthesis (uses CO2) |
| Methane (CH4) |  | Rising ocean temp releases methane | Climate Change leads to renewables |