8.1 Energy sources

1) Primary energy sources

An energy source, such as coal, wind, water, oil, that is directly used directly by the consumer.

We have these energy resources:

- 38% Oil
- 24% Natural Gas
- 24% Coal
- 6% Hydroelectric
- 6% Nuclear
- 44% Solar
- 27% Wind
- 19% Geothermal
- 0% Biomass

Practice:
Describe the origin of fossil fuels.

The sun makes biomass through photosynthesis. The biomass gathers and grows over time. It is buried under great pressure and heat. Then, it becomes oil, natural gas, and coal. Coal, oil and natural gas are extracted and used as fuels.

Reserves are resources that we can surely obtain. Production means reserves that have been obtained and placed on the market.

For e.g. oil reserves are $1200.7 \times 10^9$ barrels as of 2005.

Oil production is $29.6 \times 10^9$ barrels

Expectancy (how long they will last) = \frac{Reserves}{Production} = \frac{1200.7 \times 10^9}{29.6 \times 10^9} = 40.6 \text{ years}

These numbers can yearly change though.

2) Secondary Energy sources

An energy source, such as electricity or hydrogen, which has been transformed from a primary energy source before use by the consumer.

Electricity is convenient to use in transport.

Hydrogen only produces water after consumption.
3) **Specific energy and energy density of fuel source**

- **Specific energy** is how much energy (J) is released by 1 kg of a fuel.

\[ E_s = \frac{E}{m} \]

- **Energy density** 
  \[ E_D = \frac{E}{V} \] is how much energy (J) you can get per volume (m³).

**Example**

Fission of Uranium-235 produces \(3.5 \times 10^{11}\) J energy. Density of U-235 is \(1.8 \times 10^4\) kg m⁻³. Calculate \(E_s\) and \(E_D\) of U-235.

**Solution**

\[ E_s = \frac{3.5 \times 10^{11}}{1.5 \times 10^6} = 2.3 \times 10^5 \text{ J kg}^{-1} \]

\[ E_D = \frac{3.5 \times 10^{11}}{2.35 \times 10^{12}} = 1.5 \times 10^{-1} \text{ J m}^{-3} \]

Nuclear fuels

- Protons and Uranium-235: Specific energy
  - 3,000,000,000 and 9,000,000 MJ/kg

Fossil fuels

- Petrol: 46.9 MJ/kg
- Crude oil: 41.9 MJ/kg
- Sugar: 12.0 MJ/kg
- Household waste: 10.0 MJ/kg

4) **Renewable resources** (can be replaced in some time) vs. **Non-renewable resources**

Sun-derived sources

- **Wood**
- **Biomass**
- **Solar energy**
- **Hydroelectric**
- **Wind**
- **Photovoltaic**

Non-sun derived sources

- **Coal**
- **Oil**
- **Gas**
- **Hydrogen**
- **Uranium**
- **Chemical**
- **Non-nuclear**

**Non-Fuels**

- **Tidal**
- **Geothermal**
Solving $E_p$ and $E_d$ problems

Coal has $E_p = 32.5 \text{ MJ/kg}$. If a city has a coal-powered plant that needs to produce 300 MW of power, with an efficiency of 25%, how many kilo of coal needed daily?

\[
\frac{300 \text{ MW}}{120 \text{ MW}} \times 100 = 25
\]

Input power = 120 MW

Input energy per day = \[120 \text{ MW} \times 86400 = 10368000 \text{ MJ}\]

\[
\frac{10368000}{32.5} = 3.2 \times 10^5 \text{ kg}
\]

If a nuclear power plant powered by uranium-235 has same output & efficiency, kilograms burnt per day? per year?

\[
\frac{10368000 \text{ MJ}}{9000000} = 0.1152 \text{ kg/day}, \quad 428 \text{ kg/year}
\]

Advantages of a submarine to use nuclear source instead of diesel:

1. Nuclear reactors don't use oxygen, so can stay under water for months.
2. Very compact compared to diesel. So, the submarine can cruise far before refill.

Sankey Diagrams

Second rule of thermodynamics states that although it is possible to convert mechanical energy completely into thermal energy, it is NOT possible to convert all heat energy into mechanical energy.

The loss of energy during one form conversion is called ENERGY DEGRADATION.

Sankey Diagram of hot-air balloon:

- Chemical energy
- Potential energy
- Kinetic energy
- Electrical energy
In each stage of an ecosystem, 90% energy is lost to environment.

- 10,000 J
- 100 J
- 1000 J
- 100 J
- 10,000 J
- 1,000 J
- 1,000 J
- 100,000,000 J sunlight

1) Electricity as a secondary and versatile form of energy
   Easily transportable and distributed.
   Moving electrons can produce a magnetic field.
   Moving magnetic field can also produce electrons.
   Essentially, an electromotive force (EMF) is a voltage that can drive an electrical current.

1) The wire coils in a generator experience reversing magnetic fields as they rotate through action of a turbine of some sort, usually driven by a primary energy source.
2) This changing field produces the EMF.
3) This EMF drives the charges and creates a current.

- Note how the direction of current keeps changing.
- This is why house current is called alternating current (AC). This is the reason...
**Describing Fossil Fuel Power Stations**

**Oil/Coal-burning power plant** generates electricity most commonly.

1. Chemical energy released by burning coal.
2. Heat boils water.
3. Steam rotates a turbine.
4. Turbine turns a coil of wire in a magnetic field.
5. Electric power is produced.

---

**Gas-burning power plant**

Similar to coal power plant with one difference - it also produces electricity directly.

Overall, 50-90% efficient.
9) Describe nuclear power stations

They are the same as fossil fuel stations, from the turbine onwards.

\[ \text{Nuclear} \rightarrow \text{Heat} \rightarrow \text{Kinetic energy} \rightarrow \text{Electrical energy} \]

0) What is wrong with the diagram below?

\[ \text{Energy used for processing fuel} \]

Energy in uranium ore \[ \rightarrow \text{Energy in enriched uranium} \rightarrow \text{Electrical energy} \rightarrow \text{Energy remaining in spent fuel} \rightarrow \text{Heat} \]

Solution

There should be heat steam and kinetic energy before electrical energy and there is heat loss and friction.

Methods of enriching uranium-235

1) Gaseous diffusion - method of enriching uranium - slow & expensive

1) Uranium is combined with fluorine to make a gas uranium hexafluoride UF₆.

2) The process of diffusion uses many stages of membrane filters.

2) Centrifuging - also slow and expensive

1) UF₆ is spun and the heavier isotopes are decanted while the lighter ones are sent to further stages.

Because of the energy expenditure in the enrichment process, it is often included in the Sankey Diagram.

About reactor core in a nuclear plant

- Nuclear fission is the splitting of a large nucleus into two smaller (daughter) nuclei.

\[ ^{235}\text{U} + ^{1}\text{n} \rightarrow \left(^{236}\text{U}^\text{x}\right) \rightarrow ^{140}\text{Xe} + ^{94}\text{Sr} + 2\left(^{1}\text{n}\right) \]

- If the two neutrons hit other nuclei and split other nuclei, we call it a chain reaction.

- Chain reaction is also called uncontrolled reaction.
- There are control rods that absorb product neutrons in a controlled reaction.
- Critical mass - the minimum mass of a fissionable material which will sustain the fission process by itself.

- If kinetic energy of a neutron is too high, it can pass through $^{235}\text{U}$ nucleus without splitting it.
- If the neutron is too slow, it will just bounce off the $^{235}\text{U}$ nucleus without exciting the nucleus at all.

- Most of the neutrons produced in a reactor are fast neutrons, so they don't split the $^{235}\text{U}$ nucleus.
- These neutrons are captured by $^{238}\text{U}$, or they leave the surface of fuel rod without sustaining the fission reaction.
- Moderators (graphite, light, water) slow these neutrons to 0.02 eV so they can contribute to the fission process.
- Control rods are neutron-absorbing. They shut, start, and change the reaction rate in a reactor. Outwards:
  - Taking control rods will increase reaction rate (not positive) (retracting).
  - Inserting control rods will decrease reaction rate.
- Made of cadmium or boron steel.

- The reactor basically produces heat through fission.
- Everything is surrounded by water or a thermal absorber, that can be circulated.

Then...

The heat exchanger extracts heat, turns it into steam to run the turbine.

10) Solving problems relevant to energy transformations

| Question | $^{235}\text{U} + {}_0^1\text{n} \rightarrow ^{144}\text{Ba} + ^{90}\text{Kr} + ^{2}{}^0\text{He} | 5\% |
| Reaction | Fission reaction | b) Describe how the reaction can initiate a chain reaction?
| Energy is liberated in the reaction in what form? | Heat, and kinetic energy in neutrons. |
| One neutron causes one fission. | 1 fission produces 2 neutrons. This can initiate 2 fission and so on. So, this is a self-sustaining chain reaction.
Why is the moderator necessary?

To slow down neutrons. Fast neutrons pass through without splitting the nuclei.

Explain the function of control rods?
They absorb neutrons produced by fission to stop the reactor from becoming a dangerous chain reaction and maintain a steady self-sustaining reaction.

What happens after reactor pile
Reactor coolant is circulated through a heat exchanger which heats up water to run a steam turbine. The turbine turns a generator to produce electricity.

(1) \[ ^{235}U + {}^{1}n \rightarrow ^{144}Xe + ^{90}Sr + 2{}^{1}n \]

Show what is the energy released?
Rest masses MeV\(^{-2}\)
\[ ^{235}U \leq 2.1895 \times 10^{5} \]
\[ ^{144}Xe \leq 1.3408 \times 10^{5} \]
\[ ^{90}Sr \leq 8.3749 \times 10^{4} \]
\[ ^{1}n \leq 9.39 \times 10^{5} \]

\[ 2.1895 \times 10^{5} - 1.3408 \times 10^{5} - 8.3749 \times 10^{4} - 9.39 \times 10^{5} = 181.44 \text{ MeV}^{-2} \]

\[ 181.44 \times 10^{6} \text{ eV}^{-2} \]

Energy: \[ 181.44 \times 10^{6} \text{ eV} = 2.9 \times 10^{11} \text{ J} \]
1) Describing wind generators

- Water (c is big) Heats/cools slowly
- Land (c is small) Heats/cools quickly

1) Heated land and air becomes less dense, and rises.
2) Cooler air then fills the low pressure left behind.
3) A convection current forms.
4) Wind turbines can use the wind to make electricity.

12) Solving problems relevant to energy transformations

\[ d = vt \]

(1) Determine the power that may be delivered by a wind generator, assuming that the wind kinetic energy is completely converted into mechanical energy.

- Assume the blade is of radius \( r \).
- The volume of air that moves through the blades in a time \( t \) is \( V = A_d = At \), where \( v \) is speed of air and \( A = \pi r^2 \).
- The mass \( m \) is thus \( m = \rho V = \rho Avt \).

\[ E_k = \frac{1}{2} m v^2 = \frac{1}{2} \rho A v t v^2 = \frac{1}{2} \rho A v^3 t. \]

- Power is \( \frac{E_k}{t} \), so that

\[ \text{Power} = \frac{1}{2} A \rho v^3 \quad \text{where} \quad A = \pi r^2 \]

Wind Generator

- Since the air still moves after passing through the blades, not all kinetic energy is used. There is an efficiency level. Generally 60-80%.
**Question**

Given a turbine of blade length 12 m, a wind speed of 15 m\(^3\) and an efficiency of 45%, find the power output. The density of air is \( \rho = 1.2 \text{ kg m}^{-3} \).

\[
P = \frac{1}{2} \rho A v^3
\]

\[
P = \left( \frac{1}{2} \times (\pi \times 12^2) \times 1.2 \times 15^3 \right) \times \frac{45}{100}
\]

\[
= 410 \text{ kW}
\]

**Question**

Air of constant density 1.2 kg m\(^{-3}\) is incident at a speed of 9.0 m\(^{-1}\) on the blades of a turbine. Blade length 7.5 m. After passing, air speed is 5 m\(^{-1}\).

Density of air after passing is 2.2 kg m\(^{-3}\). Turbine and generator have overall 72% efficiency.

Calculate

(i) the power extracted from the air by the turbine.

Power \( = \frac{1}{2} m v^2 \)

\[
= \frac{1}{2} \times \rho \times A \times v^3
\]

\[
= \frac{1}{2} \rho A v^3
\]

Incident \( \text{KE power} \)

\[
= \frac{1}{2} \times (\pi \times 7.5^2) \times (1.2) \times (9^3)
\]

\[
= 77295 \text{ J}
\]

\[
= 77000 \text{ J}
\]

Afterwards \( \text{KE power} \)

\[
= \frac{1}{2} \times (\pi \times 7.5^2) \times (2.2) \times (5^3)
\]

\[
= 24000 \text{ J}
\]

\[
\text{KE extracted} = 77000 - 24000 = 53000 \text{ J}
\]

\[
\text{Power extracted} = 53000 \text{W}
\]
ii) The electrical power generated.

Overall efficiency is 72% night.

So, \[ \frac{53000 \times 72}{100} = 38000 \text{ MW} \]

**Advantages**

1. Wind power doesn't produce greenhouse gas.
2. Wind power is a renewable resource.

**Disadvantages**

1. Wind depends on weather.
2. \( \frac{2 \text{ GW}}{0.8 \text{ MW}} = 2500 \) turbines required

13) Describe hydroelectric systems

- Sun-derived potential energy
- Tidal-derived potential energy

- Sun-driven evaporation and rain place water at high potential energy.
- During less energy demand, excess power plant electricity can be used to pump water back up into reservoir for later use. This is called the pumped storage scheme.
- Pumped storage alleviates blackouts. They occur when electrical supply & demand differ by 5%.

- The turbine can be driven both way during a tidal cycle.

In both systems:

- Energy in sunlight/river to potential energy in reservoir
- Potential energy to kinetic energy of turbine
- Kinetic energy of turbine to electricity
  - 1. Evaporation
     - 2. Friction
     - 3. Friction from reservoir
Practice - reservoir is shown for hydroelectric dam is shown:

1) Calculate potential energy yield.

Total volume of water
\[ V = 1700 \times 50 \times 2500 \]
\[ = 2.125 \times 10^8 \text{ m}^3. \]

Mass of water
\[ m = \rho V = (1000)(2.125 \times 10^8) = 2.125 \times 10^{11} \text{ kg} \]

Average water height
\[ = \frac{75 + 125}{2} = 100 \text{ m} \]

Potential energy yield
\[ E = mgh \]
\[ = 2.125 \times 10^{11} \times 9.81 \times 100 \]
\[ = 2.08 \times 10^{14} \text{ J} \]

b) If water flow is $25 \text{ m}^3 \text{s}^{-1}$, what is the power provided by moving water?

\[ m = \rho V \]
\[ m = 1000 \times 25 = 25000 \text{ kg} \text{ flows per second} \]

Power
\[ P = 25000 \times 9.81 \times 100 \]
\[ = 2.5 \times 10^{10} \text{ W} \]
\[ = 25 \text{ MW} \]

2) How long can the reservoir produce power at this rate?

\[ \frac{2.08 \times 10^{14}}{25 \times 10^6} = 8320000 \text{ seconds} = 96 \text{ days} \]

Describing solar energy systems
Solar energy systems get their energy directly from the sun's rays.

There are solar heating panels and photovoltaic cells.

Sun radiates energy at a rate of $3.90 \times 10^{26} \text{ W}$, with intensity

Earth's radius is $1.5 \times 10^{11} \text{ m}$.

\[ I = \frac{P}{A} \]
\[ \frac{3.9 \times 10^{26}}{4 \pi (1.5 \times 10^{11})^2} = 1380 \text{ J s}^{-1} \text{ m}^{-2}. \]
Intensity = \frac{Power}{Area} \quad \text{Intensity}

Practice

Explain why the solar intensity is different for different parts of the Earth.

Solution

a) The following diagram shows the same intensity spread out over more area. The higher the altitude,

\[
\text{Intensity} = \frac{\text{Power}}{\text{Area}}
\]

The intensity also varies with season, which is due to the tilt of the Earth.

**Photovoltaic cells**

They convert sunlight directly into electricity. Crystalline silicon is doped with phosphorus and boron impurities.

Practice

A photovoltaic cell has an area of 1.00 cm² and efficiency 10.5%.

a) If the cell is placed in a position where sun's intensity is \( I = 1250 \text{ W/m}^2 \), what is power output of cell?

\[
\begin{align*}
100 \text{ cm} &= 1 \text{ m} \\
10000 \text{ cm}^2 &= 1 \text{ m}^2 \\
0.1250 \times 0.105 &= 0.013125 \text{ W} \\
&= 0.013 \text{ W}
\end{align*}
\]

b) If the cell is at 0.500 V, what is its current output?

\[
P = VI \\
P = 0.125 \times 0.013 = 0.001625 \text{ W} \\
0.013 \div 0.0125 = 0.26 \text{ Amperes}
\]

c) If 10 of these cells are placed in series, what will voltage and current be?

\[
V = 0.5 \times 10 = 5 \text{ V} \quad \text{Increases} \\
I = 0.026 \text{ Amperes} \quad \text{Remains same}
\]

d) How many cells for 100 W circuit?\[
\frac{100}{0.013} = 7693 \text{ cells}
\]
6) Photovoltaic cell of area $6.5 \times 10^4 \text{ m}^2$ is situated on the roof of a house. Cell efficiency is 8%. When solar radiation incident on the cell is max, cell delivers $47 \text{ mW}$ to external circuit.

1) Deduce the maximum value of power of solar radiation incident on cells.

\[
\frac{47 \text{ mW}}{8} \times 100 = 587.5 \text{ mW}
\]

\[
I = \frac{587.5 \text{ mW}}{6.5 \times 10^{-4} \text{ m}^2} = 9.0 \times 10^5 \text{ mW m}^{-2} = 0.90 \text{ kW m}^{-2}
\]

7) Why solar radiation doesn’t have constant value at a region?

1) Cloud cover variation is a reason.
2) Season is another reason.

---

**An 8.0% efficient photovoltaic cell**

<table>
<thead>
<tr>
<th>Energy in Incident Sunlight</th>
<th>Usable electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wasted heat</td>
<td></td>
</tr>
</tbody>
</table>

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**Heating Panels**

Converts sunlight directly into heat.

Why should a solar heater be northwards at noon in southern hemisphere?

Northern Southern exposures get more sun at southern hemisphere and vice versa. This is because of Earth's tilt.
Practice

Average power received from Sun during a six-hour period is 840 W/m². Solar heater efficiency is 35%. During the 6-hour period, 140 kg of water's temperature is increased by 25°C by the heater. Calculate minimum effective area of solar heater.

\[ E = mcA \Delta t \]
\[ E = 140 \times 4200 \times 25 \]
\[ = 14700000 \text{ J} \]

\[ \frac{14700000}{35} \times 100 = 4200000 \text{ J} = \text{ input} \]

\[ I = \frac{P}{A} \]
\[ \frac{4200000}{6 \times 60 \times 60} = 1944 \text{ W} \]

\[ A = \frac{4200000}{1944} = 2.3 \text{ m}^2 \]

3.2 Thermal Energy Transfer

1. Conduction, convection & thermal radiation

- Three means of transferring thermal energy: conduction, convection & radiation
- Only thermal radiation can transfer heat without a physical medium like solid, liquid or gas.

Heat from burning stone

Thermal radiation - photons carry infrared energy and travel through space. When they strike you, they are absorbed as heat. This thermal energy transfer is called thermal radiation.

B. Conduction - Energy transfer from hotter to colder objects is called conduction.

Vibration at one end is transferred to the other end from atom to atom.

Higher T atoms vibrate faster, so the vibration travels towards low T end.

The rate at which \( \frac{\Delta Q}{\Delta t} \) heat is transferred depends directly on cross-sectional area and inversely with length of the conductor. Also proportional to \( \Delta T \) between the 2 ends.

\[ \frac{\Delta Q}{\Delta t} = k \frac{A}{d} \Delta T \]
Example: A brick has thermal conductivity \( k = 0.7103 \text{ J/m°C} \).

Find the rate at which heat energy is conducted through the brick.

\[
\frac{\Delta Q}{\Delta t} = k \cdot A \cdot \Delta t = \frac{0.710 \times (0.5 \times 0.75 \times 90)}{2.5} \text{ J/s}
\]

\[
= 8.52 \text{ J/s}
\]

Convection

Needs a fluid as a medium.

2) Black-body radiation

A green box cannot absorb a wavelength of green light.

A black-body object absorbs all wavelengths.

As it heats up, it emits all wavelengths, called black-body radiation.

When we heat a black-body:

- Higher the temp, greater the intensity at all wavelengths.
- Higher temp, smaller wavelength of maximum intensity.

Wein's displacement law tells the wavelength at max intensity \( \lambda_{\text{max}} \) for blackbodies at temp. \( T \) in Kelvin:

\[
\lambda_{\text{max}} = \frac{2.9 \times 10^3}{T \text{ (Kelvin)}}
\]

If black body \( y \) has higher temp than black body \( x \):

Intensity \( \uparrow \) higher temp. Higher intensity for \( y \) has shorter wavelength at peak for \( y \).
3) The Stefan-Boltzmann Law

\[ P = e \sigma A T^4 \]

\( \sigma \) is the Stefan-Boltzmann constant. \( e \) for black-body is 1.

This law shows the relationship between temperature (Kelvin) of a black-body and the power emitted by the black-body's surface area.

Black-bodies absorb & emit same amount of energy.

So, Stefan-Boltzmann law works for both emission & absorption.

**Practice**

Mercury has radius of \( 2.5 \times 10^6 \text{m} \), sunny side temp. is 400°C and shady side temp. is -200°C. Treating it like a black-body, find its power.

\[ P = \sigma A T^4 \]

\( \sigma A = 5.67 \times 10^{-8} \times \pi \times (2.5 \times 10^6)^2 \]

\[ 4.4532 \times \left( \frac{673+73}{2} \right)^4 \]

\[ 8.6 \times 10^{15} \text{ W} \]

(Avg. Kelvin Temp.)

Be sure to use Kelvin temperature.

\[ P_{\text{sun}} = 1380 \text{ W m}^{-2} \]

The Solar Constant

Rate at which energy is received by Earth from Sun. Basically, intensity. Power emitted by sun divided spherical area of Earth \( \frac{4 \pi r^2}{4} \)

Emittance \( e \) of a body is a number between 0 and 1 that quantifies the emission to absorption properties of that body as compared to a black-body of the same size. Charcoal = 0.95.
4) Albedo

We define Albedo in terms of scattered & incident power:

\[
\text{Albedo} = \frac{P_{\text{scattered}}}{P_{\text{incident}}} \quad \text{black-body \& has an albedo of almost 0.}
\]

Affected by landforms, vegetation, weather & seasons affect a planet's albedo.

Earth's mean yearly albedo is 0.3 (30%).

(a) Assume Albedo of 0.30, what is power received by Earth?

\[
0.70 \times 10^8 \times 1.27 \times 10^{10} = 1.23 \times 10^7 \text{W}
\]

(b) Predict temp at Earth

\[
P = \frac{1}{3} A T^4 + \frac{1.23 \times 10^7}{5.67 \times 10^8 \times 4 \pi (6.37 \times 10^6)^2}
\]

\[
T = 255 \text{K}
\]

(c) If the average temp at Earth is 289 K, find its emissivity.

\[
P = 1.23 \times 10^7
\]

\[
1.23 \times 10^7 \times e \times 10^{20} = 4 \pi \times 3.89 \times 6.37 \times 10^6 \times 289^4
\]

\[
e = 0.61
\]

Incident intensity

\[
\frac{440 \text{ W/m}^2}{240 \text{ W/m}^2} = \frac{100}{84.1} = 0.29
\]
5) The Greenhouse Effect

1. Solar radiation strikes a planet, the gases in atmosphere can absorb infrared radiation (heat).
2. Remaining radiation strikes ground, and gets absorbed, or scattered back into atmosphere.
3. Solids can absorb all frequencies of radiation, and convert them to infrared wavelengths.
4. The heated ground emits infrared radiation back into atmosphere, which then intercepts more energy on the way out and radiates it back to Earth.
5. Conclusively, atmosphere traps heat and planet's temperature rises.

**This is the Greenhouse Effect**

- The gases are mainly methane (CH₄), water vapor (H₂O), carbon-dioxide (CO₂) and nitrous oxide (N₂O).

**Anthropogenic means "human".**
- Anthropogenic CO₂ emissions are exceeding atmospheric CO₂ emissions.
- The level of CO₂ is determined by observatories & aircraft.

- It is like chapter 7.
  - Heat (photons) can get absorbed by gases. The electron in the gas can jump to a different energy level.
  - The excited gases deexcite and release photons, which is called scattering.
  - Scattering does not increase net heat in atmosphere.

- Sometimes, the molecules can absorb the heat. Their random kinetic energy increases. But, not potential energy.
  - Extended molecule such as CO₂ can store kinetic energy by: Vibration, Translation and Rotation.

- Different gases absorb different wavelengths of photons.
6) Energy Balance in Earth System

- Since intensity of solar radiation depends on which part of Earth's surface area it falls, not all surfaces receive $1380 \text{ Wm}^{-2}$.

**Average is**

\[ I_{\text{avg}} = \frac{1380}{4} = 340 \text{ Wm}^{-2} \]

**Average incident solar radiation**

\[ I_{\text{avg}} = 340 \text{ Wm}^{-2} \]

Since Albedo is 0.3, $(0.7)(340) = 240 \text{ Wm}^{-2}$ is transmitted only.

7) Sankey Diagram for earth without greenhouse gases.