Topic 8. Energy Production

8.1 Energy sources

Date

Data booklet reference

- Power = $\frac{energy}{time}$
- Power = $\frac{1}{2} A \rho v^3$

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

} Fossil Fuels (CO_2)

- 6 % Hydroelectric
- 6% Nuclear
- 2% —
  - 44 % Solar
  - 27% Wind
  - 17% Geothermal
  - 12% 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 1200.7×10^9 barrels
oil production is 29.6×10^9 barrels
as of 2005.

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

$$= 40.6 \text{ years}$$

These numbers can yearly change though.

) 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 ~~has~~ is convenient ~~to be~~ to use in transport.

Hydrogen only produces water after consumption.

Date

3) Specific energy and energy density of fuel sources

- Specific energy (E_{sp}) is how much energy (J) is released by 1 kg of a fuel. $J\,kg^{-1}$ $\frac{E}{m}$
- Energy density E_D is how much energy (J) you can get per volume (m^3). $J\,m^{-3}$ $\frac{E}{\rho}$

Example

Fission of Uranium-235 produces 3.5×10^{-11} J energy. Density of U-235 is 1.8×10^{4} $kg\,m^{-3}$. Calculate E_{sp} and E_D of U-235.

Solution

$$E_{sp} = \frac{3.5\times10^{-11}}{235\times1.661\times10^{-27}} = ~~1.5\times10^{-10}\,J\,kg^{-1}~~ ~~3.9\times~~ 9.0\times10^{13}\,J\,kg^{-1}$$

$$E_D = \frac{3.5\times10^{-11}}{\frac{235\times1.661\times10^{-27}}{1.8\times10^{4}}} = \frac{3.5\times10^{-11}\times1.8\times10^{4}}{235\times1.661\times10^{-27}} = 1.6\times10^{18}\,J$$

Nuclear fuels	Specific energy
Protons and Uranium-235	300000000 and 90000000 MJ/kg ($3\times10^{8}\,MJ\,kg^{-1}$, $9\times10^{7}\,MJ\,kg^{-1}$)
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) / Non-renewable resources

Sun-derived sources

Renewable:
- fuels: Wood, Biomass
- Non-fuels: Solar energy, Hydroelectric, Wind, Wave, Photovoltaic

Non-renewable:
- Coal, Oil, Gas } fuels

Non-sun derived sources

Renewable:
- Non-fuels: Tidal, Geothermal

Non-renewable:
- Hydrogen, Uranium, Chemical } Fuels
- Chemical } non-fuels

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Date

5) **Solving Esp and E_D problems**

Coal has Esp 32.5 MJ/kg. If a city has a coal-powered plant that needs to produce 30.0 MW of power, with an efficiency of 25%, how many kilo of coal needed daily?

$$\frac{30.0\,MW}{x} \times 100 = 25$$

$x = 120\,MW$

Input power = 120MW

Input energy per day: $120MW \times 86400 = 10368000\,MJ$

$$\frac{10368000}{32.5} = 3.2 \times 10^{5}\,kg$$

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

$$\frac{10368000\,MJ}{90000000} = 0.1152\,kg \text{ a day}, \; 42\,kg \text{ a year}$$

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

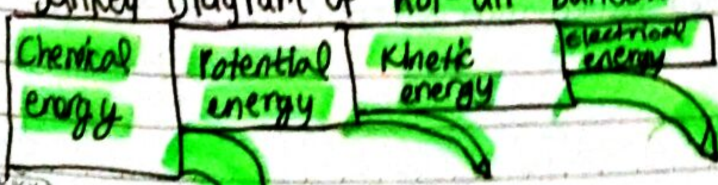
1) Nuclear reactors don't use oxygen, so can stay under water for months.
2) Very compact compared to diesel. So, the submarine can cruise far before refill.

6) **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 ~~from one ... form~~ conversion is called ENERGY DEGRADATION.

Sankey Diagram of hot-air balloon:



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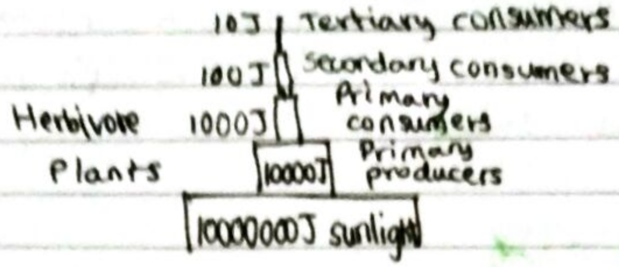
In each stage of an ecosystem, 90% energy is lost to environment.



7) 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 moving electrons.

Essentially, an electromotive force (emf) is a voltage that can drive an electrical current.

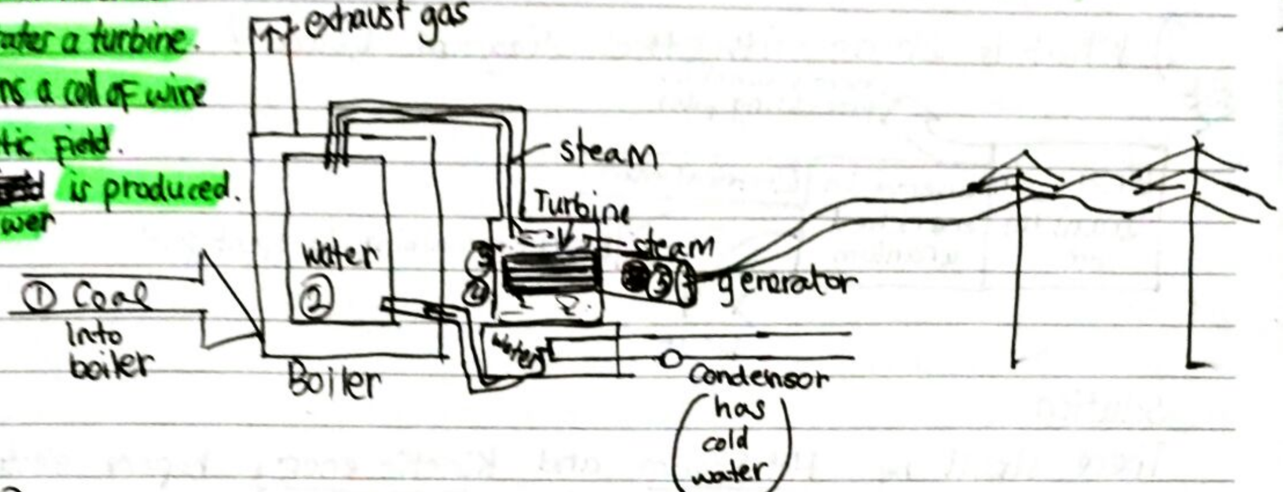
1) The wire coils in a generator experience reverse magnetic fields as they rotate through action of a turbine of some sort, usually driven by a primary energy source.
2) This changing field produces the EMF.
3) This EMF drives the charges and creates a current.

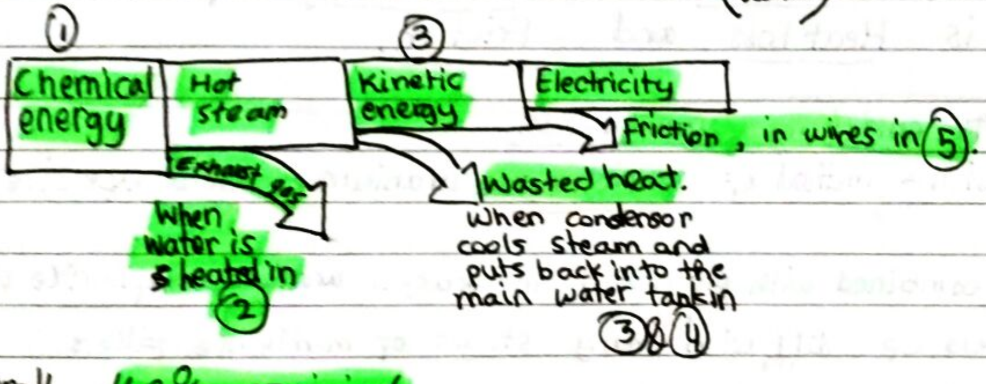
- Note how the direction of current keeps changing. ~~This is why~~
- This is why our house current is called alternating current (AC). ~~This is the reason~~

8) **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 ~~[illegible]~~ power is produced.

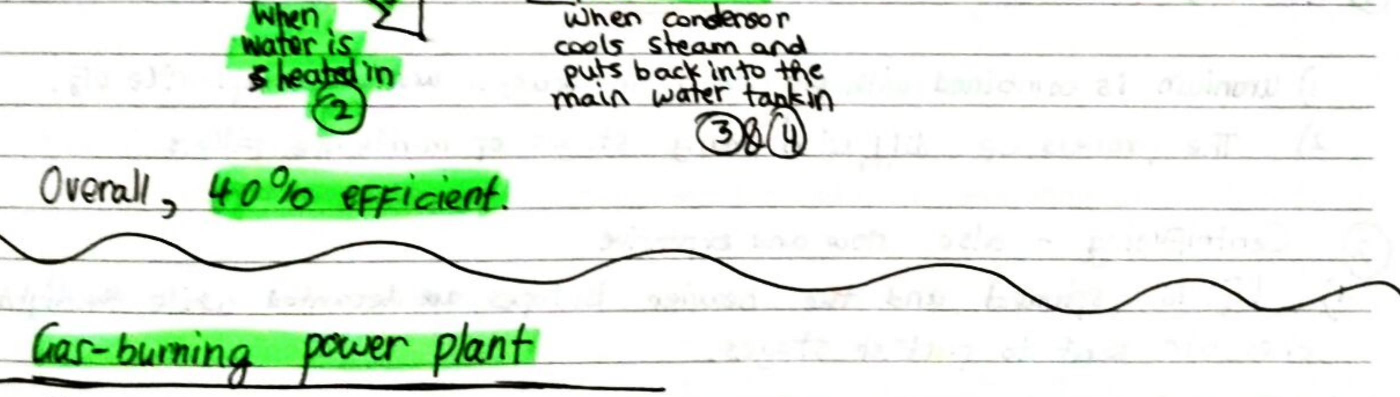


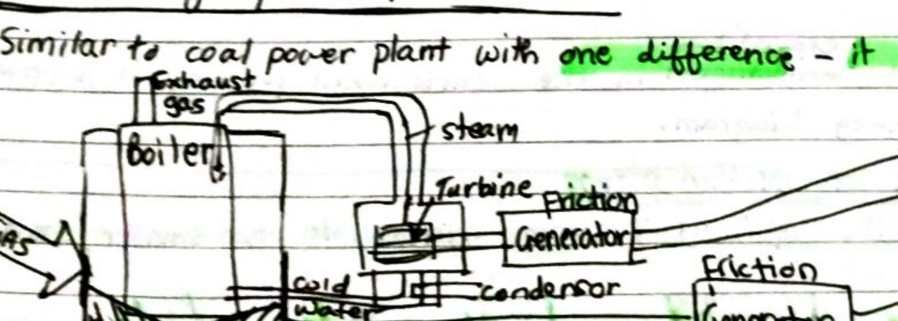


Overall, **40% efficient.**

Gas-burning power plant

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





Overall, **50 % efficient.**

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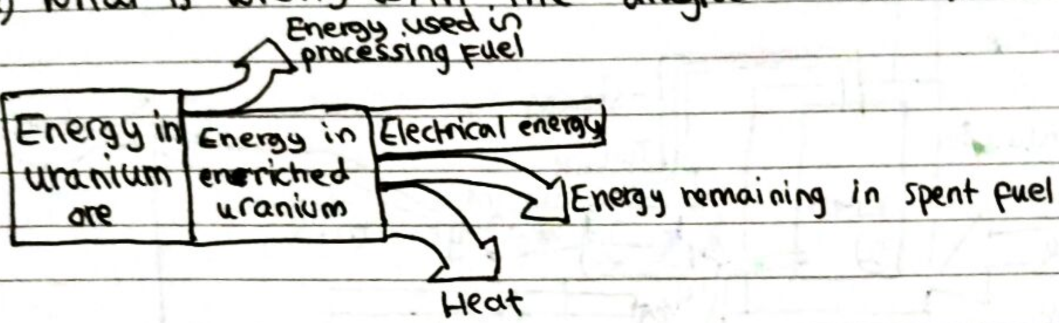
9) Describe nuclear power stations

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

Nuclear energy → Heat → Kinetic energy → Electrical energy

Q) What is wrong with the diagram below?



Solution
There should be Hot 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 UF_6.
2) The process of diffusion uses many stages of membrane filters.

② Centrifuging - also slow and expensive

1) UF_6 is spinned and the heavier isotopes are decanted while the lighter ones are sent to further stages.

Because of the energy ~~enrichment~~ 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.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow ({}^{236}_{92}U^{*}) \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2({}^{1}_{0}n)$$

- If the two neutrons hit ~~other~~ 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.

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- 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}U nucleus withous splitting it.
- If the neutron is too slow, it will just bounce off the nucleus of ^{235}U without ~~splitting it~~ exciting the nucleus at all.

- Most of the neutrons produced in a reactor are fast neutrons, so they don't split the ^{235}U nucleus.
- These neutrons are captured by ^{238}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.
  - Taking control rods ~~out~~ outwards will increase reaction rate. ~~(not fully out)~~ (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 and turns it into steam to run the turbine.

10) Solving problems relevant to energy transformations

Question. $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2\,^{1}_{0}n$

a) Reaction? Fission reaction

b) Energy is liberated in the reaction in what form? Heat, and kinetic energy in neutrons.

b) Describe how the reaction can initiate a chain reaction?

One neutron causes one fission. 1 fission produces 2 neutrons. This can initiate 2 fissions and so on. So, this is a self-sustaining chain reaction.

Date

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.

Q) $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{54}Xe + ^{90}_{38}Sr + 2\,^{1}_{0}n$

~~Show~~ What is the energy released?

Rest masses $MeVc^{-2}$

$^{235}_{92}U \leftarrow 2.1895 \times 10^5$

$^{144}_{54}Xe \leftarrow 1.3408 \times 10^5$

$^{90}_{38}Sr \leftarrow 8.3749 \times 10^4$

$^{1}_{0}n \leftarrow 939.56$

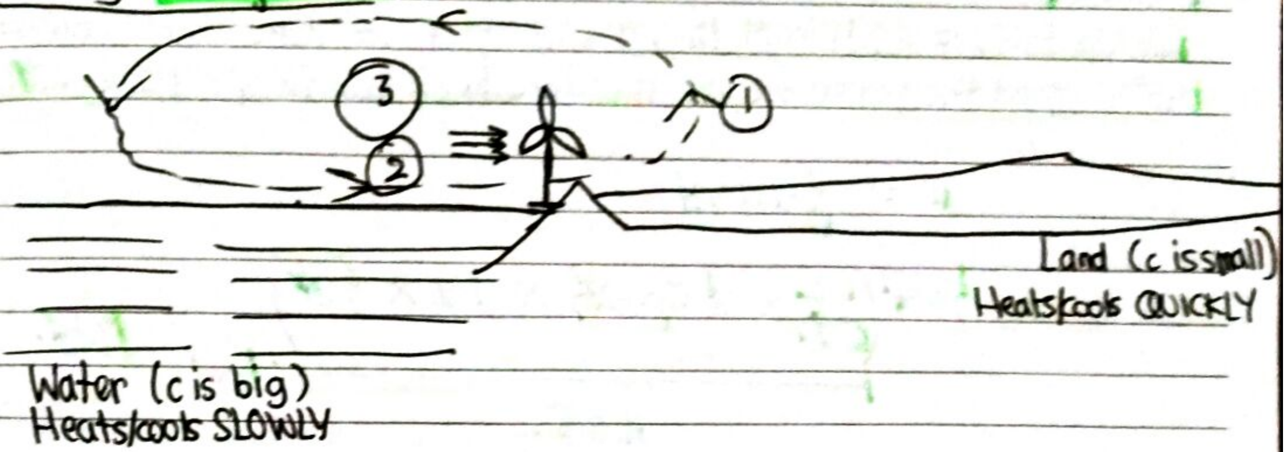
$2.1895 \times 10^5 - 1.3408 \times 10^5 - 8.3749 \times 10^4 - 939.56$

$= 181.44\ MeVc^{-2}$

$= 181.44 \times 10^6\ eVc^{-2}$

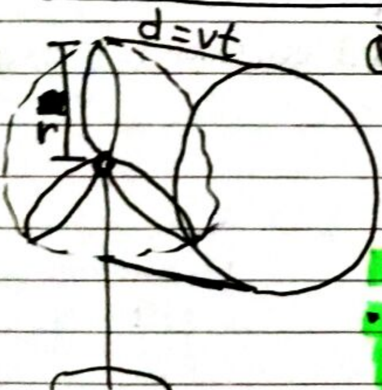
Energy $= 181.44 \times 10^6\ eV = 2.9 \times 10^{-11}\ J$

11) Describing wind generators



1) Heated land 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



(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 ~~roller~~ rotor blade is of radius r.
- The volume of air that moves ~~into~~ through the blades in a time t is $V = Ad = Avt$, where v is speed of air and $A = \pi r^2$.
- The mass m is thus $m = \rho V = \rho A v t$.
- $E_K = \frac{1}{2}mv^2 = \frac{1}{2}\rho A v t v^2 = \frac{1}{2}\rho A v^3 t$.
- Power is $\frac{E_K}{t}$ so that

$\text{Power} = \frac{1}{2}A\rho v^3$ where $A = \pi r^2$	Wind Generator

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

Date

Question

Given a turbine of blade length 12m, a wind speed of $15ms^{-1}$ and an efficiency of 45%, find the power output. The density of air is $\rho = 1.2 \, kg \, m^{-3}$.

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

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

$$= 410 \, kW$$

Question

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

Density of air after passing is $2.2 \, kgm^{-3}$. Turbine and generator have overall 72% efficiency.

Calculate

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

Power ~~KE~~ $= \frac{1}{2} m v^2$

$= \frac{1}{2} \times \rho \times V \times v^2$

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

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

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

Incident ~~KE~~ Power

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

$= 77295 \, J$

$= 77000 \, J$

Afterwards ~~KE~~ Power

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

$= 24000 \, J$

Power ~~KE extracted~~ = ~~77000~~ 77295 − ~~24000~~ 24298 = 53000 J

Power extracted = 53000 W

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ii) the electrical power generated.

Overall efficiency is 72% right.

So, $\frac{53000}{100} \times 72 = 38000$ kW

Wind powerplant

Advantages	Disadvantages
1) Wind power doesn't produce greenhouse gas.	1) Wind depends on weather.
2) Wind power is a renewable resource.	2) $\frac{2\,GW}{0.8\,MW}$ = 2500 turbines required

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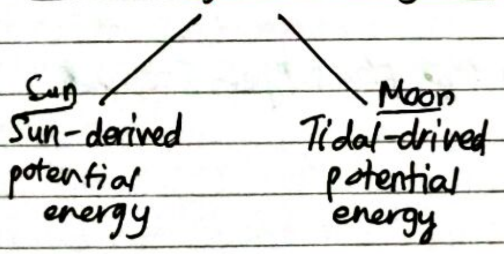
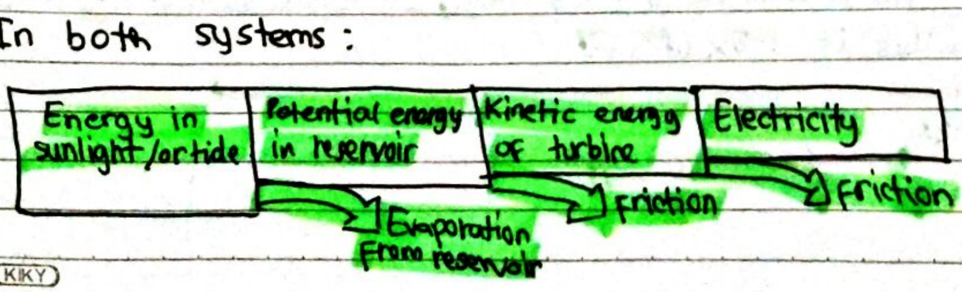
13) Describe hydroelectric systems



- 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:



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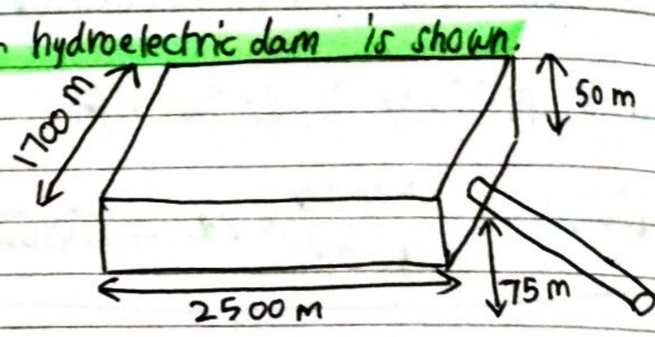
Practice - reservoir ~~is shown~~ for hydroelectric dam is shown.

a) Calculate potential energy yield.



Total volume of water is $= 1700 \times 50 \times 2500$
$= 2.125 \times 10^{8}\ m^3$.

Mass of water $= \rho V = (1000)(2.125 \times 10^{8}) = 2.125 \times 10^{11}$ kg

Average water height is : $\frac{75 + 125}{2} = 100m$

Potential energy yield $= mgh$
$= 2.125 \times 10^{11} \times 9.81 \times 100$
$= 2.08 \times 10^{14}$ J

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

~~$25\ m^3$~~ $m = \rho V$
$m = 1000 \times 25 = 25000$ kg flows per second

Power $= 25000 \times 9.81 \times 100$
Power $\approx 2.5 \times 10^{7}$ W
$= 25$ MW

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

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

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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 as a rate of 3.90×10^{26} W. What with intensity does energy reach Earth if Earth's radius is 1.5×10^{11} m?

$I = \frac{P}{A}$ $\frac{3.9 \times 10^{26}}{4\pi(1.5 \times 10^{11})^2} = 1380\ J s^{-1} m^{-2}$.

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Intensity = $\frac{Power}{Area}$	Intensity

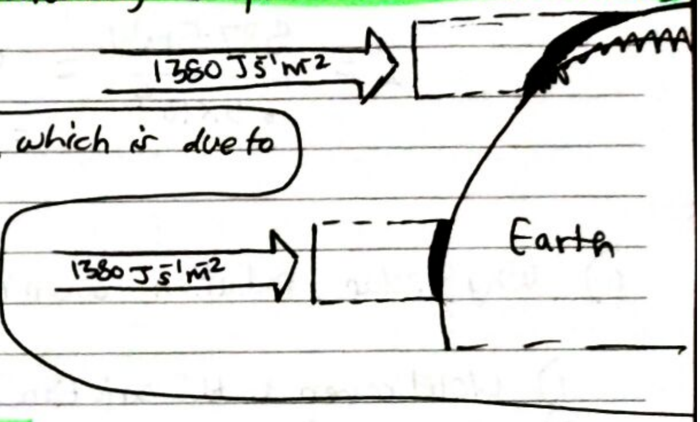
Practice

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

Solution

- The ~~following diagram shows~~ same intensity is spread out over more area, the higher the altitude.

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 ~~made of~~ doped with phosphorus and boron impurities.

Practice

A photovoltaic cell has an area of $1.00 cm^2$ and efficiency 10.5%.

a) If the cell is placed in a position where sun's intensity is $I = 1250 W m^{-2}$, what is power output of cell.

~~1250~~ 100 cm = 1 m
$10000 cm^2 = 1 m^2$

$0.1250 \times 0.105 = 0.013125 W$
$= 0.013 W$

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

$P = VI$

$P = 0.125$ [0.013125]

$\frac{0.013125}{0.5} = I =$ ~~0.25~~ 0.02625 Amperes
$= 0.026$ Amperes

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

$V = 0.5 \times 10 = 5V$. Increases

A = 0.026 Amperes. Remains same.

d) If parallel?
V = 0.5V Same
I = 0.26 A Increases

e) How many cells for 100 W circuit? $\frac{100}{0.013} = 7693$ cells

Q) Photovoltaic cell of area $6.5 \times 10^{-4}\ m^2$ is situated on the roof of a house. Cell efficiency is 8%. When solar radiation incident on the cell is max, cell delivers 47mW to external circuit.

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

$$\frac{47\,mW}{8} \times 100 = 587.5\ mW$$

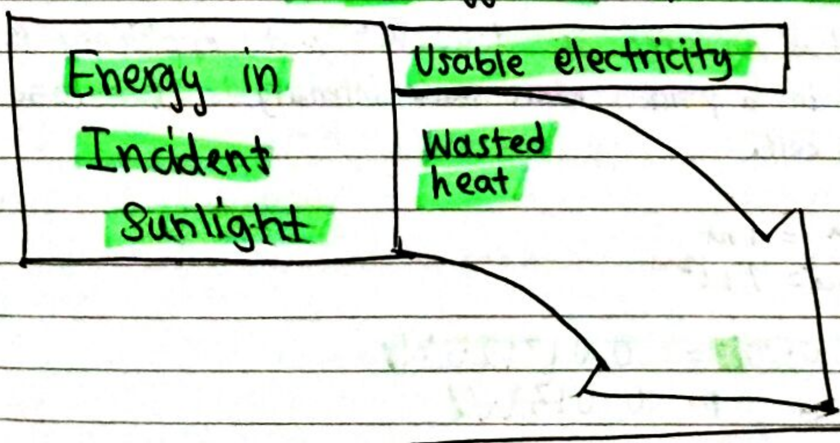
$$I = \frac{587.5\,mW}{6.5 \times 10^{-4}} = 9.0 \times 10^{5}\ mW\,m^{-2}$$

$$= 0.90\ kW\,m^{-2}.$$

Q) Why solar radiation doesn't have constant value at a region?

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

An 18% efficient photovoltaic cell



Heating Panels

Converts sunlight directly into heat.

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

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

Date

Practice

Average power received from Sun during a six-hour period is 840 Wm^{-2}. Solar heater efficiency is 35%. During the 6-hour period, 140 kg of water's ~~by~~ temperature is increased by 25K by the heater. Calculate minimum effective area of solar heater.

$$E = mc\Delta t$$
$$E = 140 \times 4200 \times 25$$
$$= 14700000\ J$$

$$\frac{14700000}{35} \times 100 = 42000000\ J = \text{input}$$

$$I = \frac{P}{A} \qquad \frac{42000000}{6\times60\times60} = 1944\ W$$

$$A = \frac{1944}{840} = 2.3\ m^2$$

8.2 Thermal Energy Transfer

i) 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.

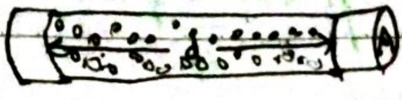
Heat from burning stove

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.

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 $\Delta Q/\Delta t$ heat (energy) is transferred depends directly on cross-section A and inversely with length d of the conductor. Also proportional to ΔT between the 2 ends.

$$\frac{\Delta Q}{\Delta t} = \frac{kA\Delta T}{d}$$ Thermal conduction



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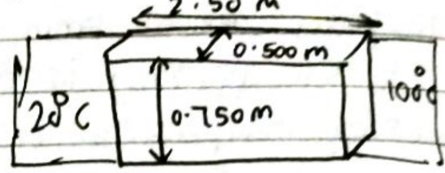
Example: A brick has thermal conductivity $k = 0.710 \, J/msC^{\circ}$.

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



$$\frac{\Delta Q}{\Delta t} = \frac{k A \Delta t}{d} = \frac{0.710 \times (0.5 \times 0.75) \times 80}{2.5}$$

$$= 8.52 \, Js^{-1}$$

Convection

Needs a fluid as a medium.

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2) Black-body radiation

A green box cannot absorb wavelength of green light.

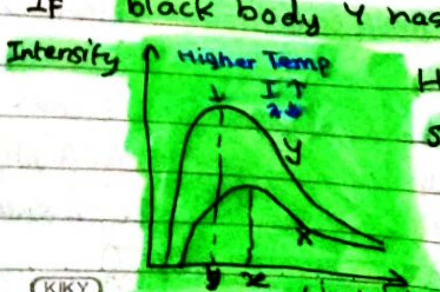
A black-body object absorbs all wavelengths.
As it heats up, it emits all wavelengths, called black-body radiation.

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 of max. intensity λ_{max} for blackbodies at temp. T in Kelvin:

$\lambda_{max} = \frac{2.90 \times 10^{-3}}{T \, (\text{kelvin})}$	Wein's displacement law

If black body Y has higher temp. than black body X:



Higher intensity for Y
shorter wavelength at peak for Y

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3) The Stefan- Boltzmann Law

$P = e\sigma A T^4$ e is emissivity $0 \leq e \leq 1$ where $\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$	The Stefan-Boltzmann Law

σ is the stefan-Boltzmann constant. ~~e~~ 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 2.50×10^6 m, sunny side temp. is 400°C and shady side temp. is -200°C. Treating it like a black-body, find its power.

$P = \sigma A T^4$

$\sigma \times A = 5.67 \times 10^{-8} \times \pi \times (2.5 \times 10^6)^2 = 445320$

$445320 \times \left(\frac{673 + 73}{2}\right)^4 =$ ~~166104645 W~~ 8.6×10^{15} W

(Avg. Kelvin Temp.)

Be sure to use Kelvin temperature.

$P_{sun} = 1380\ Wm^{-2}$	The Solar Constant

→ Rate at which energy is received by Earth from Sun. Basically Intensity. Power emitted by sun ÷ ~~and~~ spherical area of Earth $4\pi r^2$

Intensity = Power / Area

Emmisivity e of a body is a number between 0 and 1 that quantifies the emission & absorption properties of that body as compared to a black-body of the same size. Charcoal = 0.95

$e = \frac{P_{BODY}}{P_{Black\ body}}$	EMISSIVITY
$e = \frac{P_{BODY}}{\sigma A T^4}$	

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4) Albedo

We define Albedo in terms of scattered & incident power:

$$\text{Albedo} = \frac{P_{scattered}}{P_{incident}}$$ ALBEDO

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%).

Q) Assume Albedo of 0.30, what is power received by Earth.

$0.70 \times 1380 \times 1.27 \times 10^{14} = 1.23 \times 10^{17}\ W$

Q) Predict temp. at Earth

$P = \sigma A T^4$

$$\frac{1.23 \times 10^{17}}{5.67 \times 10^{-8} \times 4\pi (6.37 \times 10^{6})^2} = T^4$$

$T = 255\ K$

Q If the average temp. at earth is 289 K, find its emissivity.

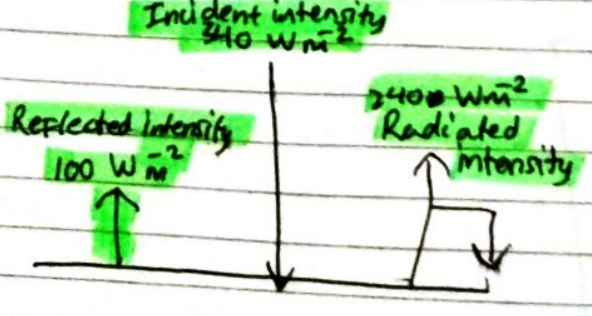
$P = 1.23 \times 10^{7}$

$1.23 \times 10^{17} = e \times 5.67 \times 10^{-8} \times 4\pi (6.37 \times 10^{6})^2 \times 289^4$

~~$e = 3.5 \times 10^{-18}$~~

$e = 0.61$

Q)



Albedo?

$$\frac{100}{340} = \frac{10}{34} = 0.29$$

KIKY

Date

5) The Greenhouse Effect

When
1) Solar radiation strikes a planet, the gases in atmosphere can absorb infrared (heat) radiation.
2) Remaining radiation strikes ground, and gets absorbed, or get 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 and gases more energy on the way out and radiate it back to Earth.
5) Conclusively, atmosphere traps heat and planet's temperature rises.

Keywords: infrared, absorb

THIS IS THE GREENHOUSE EFFECT.

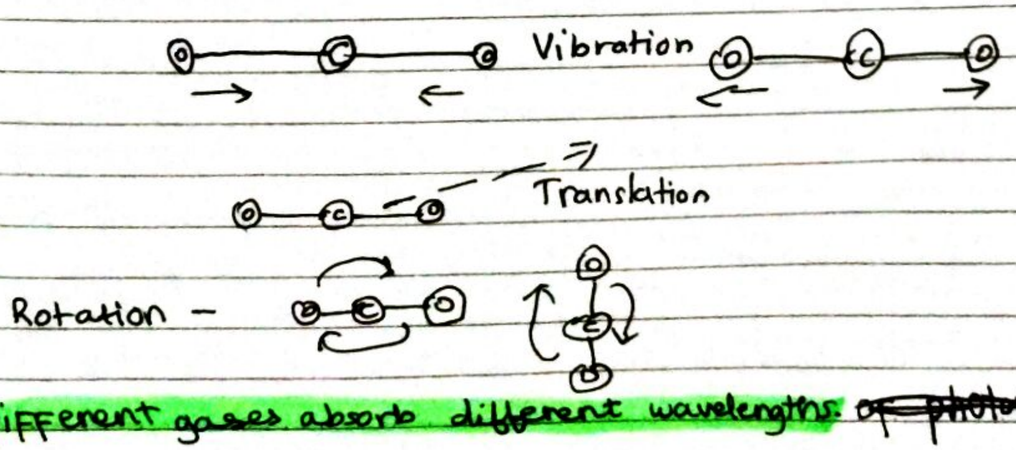
- The gases are mainly methane (CH_4), water vapor (H_2O), carbon-dioxide (CO_2) and nitrous oxide (N_2O).

Anthropogenic means "human".
- Anthropogenic CO_2 emissions are exceeding atmospheric CO_2 emissions

- The level of CO_2 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 CO_2 can store kinetic energy by: Vibration, Translation and Rotation.



- Different gases absorb different wavelengths. ~~of photons~~

Date

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 $1380\ Wm^{-2}$.

Average is

$I_{avg} = 340\ Wm^{-2}$	Average incident solar radiation

$\frac{1380}{4} = 340\ Wm^{-2}$

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

7) Sankey Diagram for earth without greenhouse gases.