08 Energy, Power and climate change review answers

Power generation

1. Copy and complete: "Thermal energy may be completely converted into **work** in a single process such as the **adiabatic** expansion of a gas but continuous conversion requires a **cyclical** process and the transfer of some energy away from the **system.**

(words to use: system, adiabatic, work, cyclical)

2. (a) What is degraded energy? **Energy that is no longer can be converted into work.**

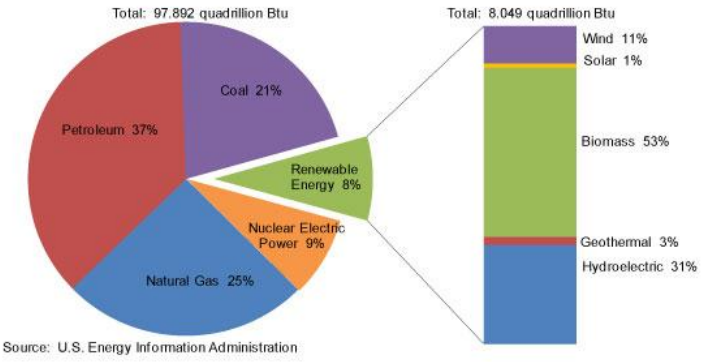
(b) Construct a Sankey (energy flow) diagram for a nuclear power station and identify the points where energy is degraded?

The most energy is wasted in exhaust gases of the turbine.

3. (a) State the relative proportions of world use of the main energy sources.

Oil 40%
Gas 25%
Coal 20%
Nuclear 10%
Renewable 10%

Figure 1. Renewable energy consumption in the nation's energy supply, 2010



(b)What is the prime energy source for most instances of energy use on Earth?

The Sun is the prime source for solar, fossil fuels and hydro-electric power. To some extent wind and wave power also has the Sun as prime source.

(c) Identify two other prime energy sources that are used on Earth.

Nuclear power energy sources are fissionable (or fusable) atoms.
Geothermal energy is coming from the Earth's centre (some of which is nuclear in origin)
Tidal power comes from the rotation of the Earth (and the action of the Moon)
Wind and wave also come partly from the rotation of the Earth.

4. What are the main technological barriers to using nuclear fusion as a source of electrical energy?

Very high temperature and pressures are needed and it is difficult to both contain the plasma and extract the energy created.

5. The table shows energy density of potential fuels: (http://en.wikipedia.org)

Fuel	Used in	Specific energy obtained (MJ/kg)
Deuterium-Tritium mix	Nuclear fusion	567,000,000
Enriched Uranium (3.5% U-235)	Nuclear fission	3,456,000
Zip fuel (/wiki/Zip_fuel)	Jet engines	70
Kerosene	Jet engine	45

Coal	Power stations	30

Use the data to answer the following questions.

(a) (i) Why, given the difficult technological barriers, is there still much interest and investment in nuclear fusion and (ii) Why, despite the risks, are many countries developing nuclear fission reactors

Nuclear fusion has the highest specific energy value so potentially the least amount of fuel needed and nuclear fission the second highest.

(b) It takes approximately 33MJ/kg to put a satellite into orbit. Why does this make it worthwhile developing Zip fuels with higher specific energies than Kerosene?

Each kg of kerosene provide 45-33 = 12MJ of energy above the energy required to put itself in orbit. (If you factor in the mass of the fuel container this figure will be reduced). If a fuel can be developed with a higher specific energy the mass of the fuel required reduces significantly.

(c) How many kg of coal does a 1000 MW **coal** plant that averages 750 MW of production over the course of day use in one day?

Energy [MJ] = Power [MW] x Time [s] = 750 x 24x60x60 = 64,800,000 MJ

Mass used = Energy / Specific energy = 64800000 / 30 = 2160,000 = 2.2×10^6 kg

(2200 tons)

6. State the approximate efficiency of: **natural gas power stations 50%, oil fired power stations 40%, coal fired powered stations 40%, combined heat and power plants 90%**

7. Neutrons are most easily absorbed by U-235 when they have energy of about 1eV. Define 1eV and explain what needs to happen to neutrons for a chain reaction to occur.

1 eV is the energy gained by one electron when accelerated by a potential of 1V. It is a small amount of energy so the neutrons must be slowed down (by a moderator) for a chain reaction to occur.

8. What environmental problems are caused by the recovery (extraction) of (a) Coal, (b) Oil.

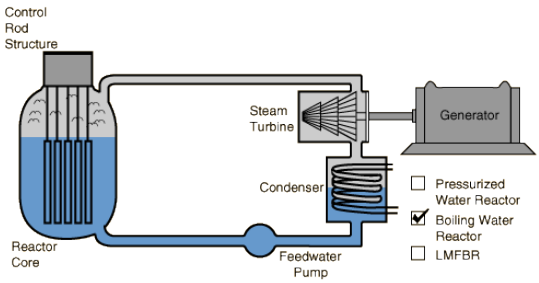
(a) Coal extraction can damage large areas of land

(b) Leaks from oil extraction can contaminate surrounding areas

9. What environmental problems are caused by the burning of fossil fuels?

Air pollution and increased levels of carbon dioxide.

10. Explain the purpose of the moderator and control rods in a nuclear power plant.



The moderator (water) slows the neutrons down so that the chain reaction continues in a stable fashion. Control rods absorb neutrons to reduce the rate of the reaction.

11. U-238 will also capture neutrons in the nuclear reactor but will not fission.

(a) What does the Uranium-238 decay into after it absorbs a neutron?

It becomes U-239 and then rapidly decays (beta decay) into Plutonium-239

(b) What can the element produced then be used for?

Nuclear fission

12. How can thermal meltdown of a nuclear reactor arise?

If, on average, more than one neutron causes a further fission reaction then more and more fission reactions occur. If this is not controlled the heat generated will cause the nuclear fuel rods to melt and possible melt/explode the reactor.

13. Why do responsible governments need to keep careful control over what happens to nuclear fuel?

It can be used to make nuclear weapons

14. Draw a labeled diagram of a photo-voltaic cell.

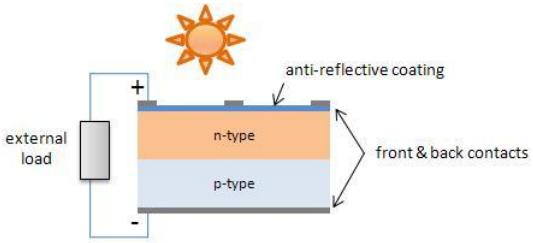
15. Draw a labeled diagram of a solar heating panel.

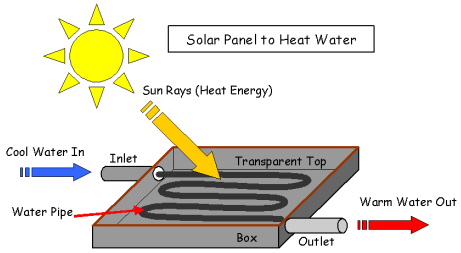
The knowledge you need for the exam is that:

In the PV cell photons from the sun move electrons between the layers to create a DC electrical supply

The solar heating panel uses sunlight falling on dark pipes with water that heats up due to the sun's rays being absorbed. The solar heating panel is covered to prevent heat loss from convection.

Energy conversions: Light energy ➔ Electrical, Light ➔ Internal heat energy





16. Explain why solar power on its own is not a cost effective source of heating for a temperate country.

The cost of making the solar panels is high and they will not be very effective in Winter.

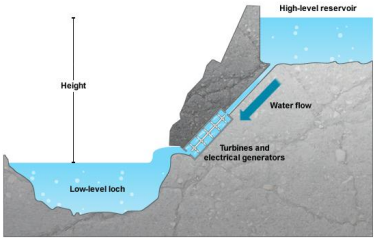
17. Draw diagrams to show the differences between the following hydro-electric power schemes.

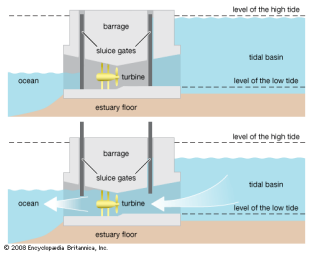
(a) water storage in lakes (b) tidal water storage (c) pumped water storage and give an advantage and disadvantage for each one.

Lake storage:

+ Clean, renewable

- Not possible in many locations or else the constructions of the dam floods large areas of land

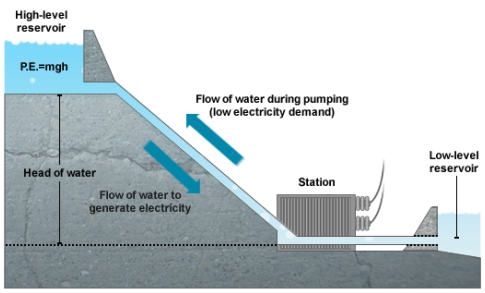




Tidal

+ Clean, Renewable

- Only works for about an hour or two every six hours, large construction often needed, can affect the estuary environment

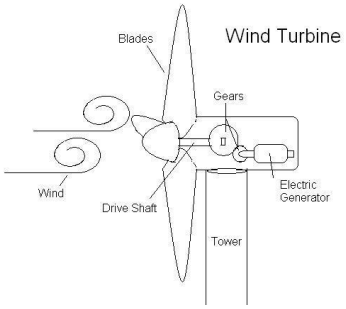


Pumped storage:

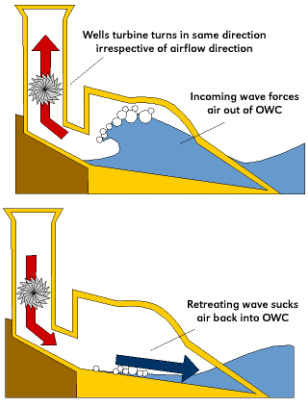
+ Energy available quickly

- Energy needed to pump water back up.

18. Draw a labeled diagram of a wind generator



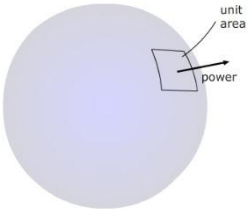
19. Draw a labeled diagram of an oscillating water column ocean wave energy converter.



Climate

The sun has a luminosity of 3.8×10^{26} W. 1 AU = $1.5\text{x}10^{11}$ m. Radius of Earth = 6380km

1. (a) Calculate the intensity of sunlight incident on the Earth



By the time the radiation reaches the earth the power has spread over an area the size of the sphere around the sun with a radius equal to the distance to the Earth.

$I = P/A = P/4\pi d^2 = 3.8\times10^{26}$ W / $4\pi(1.5\text{x}10^{11}\text{m})^2 = 1340\text{W/m}^2$

(b) Calculate the intensity incident at a surface 45 degree to the incident sunlight.

$1340\cos(45) = 950\ \text{W/m}^2$

(d) Calculate the average total solar power reaching the Earth.

Exposed are is equivalent to the area of a circle of Earth's diameter

$= \pi \text{ x } (6.38\text{x}10^6)^2 = 1.28 \text{ x } 10^{14}\text{m}^2$

$P = IA = 1340\text{x}1.28 \text{ x } 10^{14}\text{m} = 1.71 \text{ x } 10^{17}\text{W}$

(e) Calculate the average intensity received over the whole of the surface of the Earth

$I = P/A = 1.71 \text{ x } 10^{17}/4\pi(6.38\text{x}10^6)^2 = 333\text{W/m2}$

(f) Explain the difference between your answers to (a) and (d).

Answer a is the intensity received per m2 area facing the sun directly. Most of the Earth does not face the sun directly and half of it does not face the Sun at all which results in the answer d.

2. Define albedo and state what geographical features increase the albedo of the Earth.

Albedo is the ratio of reflected radiation from the surface to incident radiation upon it.
It is a reflection coefficient, [derived from Latin albus "white,"].
There are various factors that affect the Earth's albedo. Snow and ice are highly reflective so increase albedo. Forests have a lower albedo than open land so deforestation increases albedo [but for the record, no, chopping down all our forests is not the solution to global warming]. Clouds increase albedo by reflecting incoming sunlight [but can also warm the climate by trapping outgoing infrared radiation from the surface].

3. Explain, in terms of variation of absorbencies with wavelength of radiation, why "greenhouse" gases act to insulate the Earth.

"Greenhouse" gases absorb radiation in the infra-red region. This region is more important (high proportion of the energy) in the radiation leaving the Earth than it is in the radiation entering the Earth. The visible wavelengths are more important (high proportion of the energy) for the radiation entering the sun. (ref: Wein's law)

4. The level of carbon di-oxide in the atmosphere is increasing. (a) What activities of humans have been directly increasing the amount in the atmosphere? **Burning of fossil fuels.** (b) Explain how deforestation also increases the amount of carbon dioxide in the atmosphere. **Less forest means less photosynthesis which means less carbon dioxide is being absorbed from the atmosphere.**

5. Global temperature is semi-stable.

(a) What are the stabilising factors that keep global temperatures steady (variables that do not tend to change and that regulate the temperature)? **Radiation received from the Sun is quite stable. If the Earth warms then radiation from the Earth increases so this actively regulates the temperature (ref: Stefan's law). Increased temperatures increase the evaporation which increases cloud cover which cools the Earth (usually)**

(b) Explain why the amount of snow and ice near the poles of the Earth is a variable that causes instability in the climate by positive feedback.

Melting snow decreases the albedo which increases temperatures which melts more snow.

(c) Give another example of a variable which causes instability by a positive feedback.

If the oceans are warmer they release carbon dioxide which increases warming due to greenhouse effect.

6. (a) 6. (a) The surface area of the ocean is 3.6×10^{14} m^2. The coefficient of volume expansion of water is 0.000180 K^{-1}. If the oceans of the Earth have a volume of $1.3 \times 10^{18} m^3$ by how much might sea level rise would result with one degree of warming assuming that the land did not expand.

Volume increase = $1.3 \times 10^{18} m^3 \times 0.00018 K^{-1} \times 1K = 2.34 \times 10^{14} m3$.

Depth increase = $2.34 \times 10^{14} / 3.6 \times 10^{14} m^2 = 0.65m$

(b) what other consequence of global warming might make the sea levels rise? Melting of land ice and snow (c) Why are accurate predictions of sea level changes difficult to make? **Accurate predictions of temperature increase are hard and in addition the land will expand also and the amount of melting is hard to predict.**

7. Given the data in 6(a), the specific heat capacity of sea water of 4000 $Jkg^{-1}K^{-1}$ and density of 1000 kgm^3 estimate how much energy the oceans would absorb for a temperature rise of one degree.

Mass = volume x density

$Q = mC\Delta T = 1.3 \times 10^{18} m^3 \times 1000 \times 4000 \times 1 = 5.2 \times 10^{24} J$

8. The greenhouse effect is useful. Explain this statement. **Without it the planet would be too cold to support as much life as it does.**

9. Outline seven steps that humankind would need to take to reduce the enhanced greenhouse effect.

Use more renewable energies, Replant forests, Stop cutting down forests, Control population increase, Use energy more efficiently, use more nuclear power, Burn less fossil fuels.

10. What international agreements have been made to attempt to reduce the enhanced greenhouse **effect? Kyoto protocol, APP (Asia-Pacific Partnership)**