S268 Summaries Block 4-1

Section 1

1. Energy is the basis of modern society. Other physical resources can only be effectively extracted, processed and transported if there is a ready supply of energy at the right price

2. Energy (measured in joules) is defined as the capacity to do work, whereas power (measured in watts) is the rate of doing work or the rate at which energy changes from one form to another.

3. All conversions of energy are inefficient to varying degrees

4. The sun is by far the most important source of natural energy on the Earth. The solar radiation that reaches the Earth contributes to winds, waves, atmospheric water circulation, atmospheric heating and surface water evaporation, and to organic activity.

5. The gravitational pull of the Sun and the Moon combines with the Earth's axial rotation to produce tides, and the Earth is also internally hot. These are small but potentially exploitable sources of energy

6. The world is plentifully supplied with solar-derived energy, but most of it is not in a sufficiently concentrated form to make it of use to modern industrial society

7. Fuels are of immense value because they are concentrated forms of energy that can be easily stored, transported and used at will.

8. Energy sources can be subdivided into renewables, like solar, wind, and wave power, and non-renewables, like peat, coal, oil and gas. Renewables are effectively everlasting, but there is a finite amount of non-renewables.

Section 2

1. The world contains an estimated 9 x 10^{16} tonnes of carbon. Most of this is locked within carbonate rocks. An estimated 10^{13} tonnes of carbon is contained within fossil fuels.

2. Green plants use solar radiation to build carbohydrates and plant tissue from carbon dioxide and water in the atmosphere, in a process known as photosynthesis. Photosynthesis releases oxygen into the atmosphere. When they respire, organisms use oxygen from the atmosphere to generate energy from food, releasing carbon dioxide and water vapour back into the atmosphere. The respiration reaction is the reverse of photosynthesis

3. When plants and animals die, the organic material in their bodies is normally oxidised. If, however, organic material decays in an environment where oxygen supply is limited, organic compounds relatively rich in carbon and/or hydrocarbons are produced.

4. Over millions of years, the Earth's natural carbon cycle has operated to create a balance between production and use of atmospheric gases. Solar energy supply, atmospheric composition and plant growth are broadly in dynamic equilibrium.

5. Peat is a forerunner of coal. To be preserved as peat, plant growth must exceed decay and oxygen-poor conditions must become established. Swamp and bogs where the water table is at or above the surface provide an ideal environment for peat preservation. As peat swamps become loaded by sediment, water and air is squeezed out of the spaces in the lower layers and the peat compacts. Eventually coal layers may be formed, interbedded between layers of sandstone and mudstone.

6. Coal represents the fossilised remains of former land plants. Within its microscopic structure, fragments of bark, wood, spores and resin can all be found. Land plant fossils are commonly associated with coal seams, and no pre-Silurian (i.e. pre-land plants) coals are known.

7. Coal forms in low-lying estuarine and coastal regions, and is preserved where there is overall subsidence of the region and there are adequate supplies of sediments to bury the peat.

8. With continued burial, volatiles are lost and both oxygen and hydrogen decrease relative to carbon. Pressure and temperature together change low-

rank coals into high-rank coals. The calorific value of coal generally increases with increasing rank.

9. Concentrations of marine microplankton occur in the upper sunlit layers of the oceans where upwelling currents bring adequate nutrients. These form the basis of the marine food chain. There is only a build-up of carbon within marine sediments where there is an adequate supply of organic material and where physical conditions are right for its preservation.

10. To yield oil or gas, the sediments must contain sufficient organic material compared with the total rock mass, and this carbon-rich sediment must be heated to temperatures of 100-200^{o}C to convert its kerogen into hydrocarbons. This heating is achieved by burying source rocks under 2-5km of younger sediment. The length of time the source rock has been buried affects the amount of hydrocarbons generated.

11. Whether oil or gas is produced depends primarily on the type of organic material present in the source rock, the maximum temperature the source rock has reached and the time it remained at that temperature. Type III kerogen, effectively the same material as coal, sources gas when buried deeply enough. Types I and II kerogen usually source first oil, then gas with increasing burial ad/or time

12. Crude oil can be obtained artificially, from oil sand, by underground distillation from oil shales, or from hydrocarbon residues.

13. Natural carbon fluxes have not been constant over geological time. In particular, rising sea levels lead to increasing areas of shallow seas, and to an increase in marine carbon fixing. Two periods of high global sea level in the geological past, Ordovician – Silurian times and Jurassic – Cretaceous times, contain higher than usual concentrations of marine carbon-rich rocks.

14. Most carbon-rich rocks are found in sedimentary basins; but most organic material within sedimentary basins is finely dispersed and will never be commercially exploitable

Section 3

1. Coalfields can be classified as either exposed or concealed, depending whether or not the coal bearing rocks are hidden by younger strata. In most coalfields, mining commenced in the shallower exposed regions and has gradually extended into the deeper parts of the concealed coalfields.

2. Surface outcrops of rock can tell us much about whether there is a likelihood of coal at depth. Remote areas of the world are difficult to access on foot or by vehicle, so initial surveys often use data acquired from satellites or aeroplanes.

3. There are several effective and widely used exploration techniques. Drilling boreholes is expensive but is the only way to be absolutely certain of rock sequences, thicknesses and ages. Geophysical logging records the nature of the strata located in the boreholes without the need to take cores. The coals themselves are cored for chemical analysis, though.

4. Most deep coal is extracted nowadays using the longwall methods and mechanised systems. Such coal cutting systems are very inflexible and are incapable of negotiating many of the geological variations likely to be met. An understanding of the probable geological variations underground is therefore essential, both for selecting working areas and maintaining the continuity of face operations.

5. Surface or opencast mining is flexible, cheap system that is currently producing most of the world’s exported coal. Opencast mining is limited only by the stripping ratio of the overburden to coal

6. Opencast mining results in short-term local environmental disturbances; underground mining provides longer lasting problems, owing to spoil heaps, subsidence and drainage

7. The oldest coalfields are of Carboniferous age which formed in tropical latitudes. The Permian or Triassic coalfields of the southern hemisphere originated in temperate latitudes. Brown coals make up half of the worlds coal reserves; mainly they are Jurassic to Tertiary in age. Extensive Tertiary deposits of low rank coal are worked in Eastern Europe.

8. Coal reserves can be calculated roughly on a straightforward basis of multiplying the area of occurrence by thickness of seam and the density of the

coal. However, many geological factors affect this calculation. For accurate reserve estimations, detailed geological and geophysical surveys and drilling programmes must be undertaken. In 1993, the world has reserves of 1039 billion tonnes of coal, which at 1993 rates of production would last beyond the year 2229.

9. Demand for coal has fallen in Britain over the last twenty years, because of technological, economic and political factors. Britain’s current coal demands could be met without using any deep mined coal.

Section 4

1. Fluid petroleum migrates for two reasons. As a sedimentary sequence is buried, the sediments compact, losing pore space between grains. Water and petroleum are thus expelled from between the mineral grains. Excess pressure also helps to expel hydrocarbons from the source rock as it matures. Petroleum moves in response to the pressure gradient set up within the rock. Fluids can move upwards, sideways or even downwards, depending on the detailed local pressure gradient.

2. For petroleum to become concentrated enough to represent a substantial oil or gas accumulation, it must be retained within suitable reservoir rocks.Reservoir rocks must be porous enough to contain substantial amounts of petroleum and they must also be permeable enough to allow fluids to flow into and out of the reservoir. Igneous and metamorphic rocks are usually unsuitable reservoir rocks; almost all reservoir rocks are sedimentary rocks.

3. Permeable reservoirs must be capped by impermeable seals, usually shales and evaporates

4. Structural traps are formed by the deformation of sedimentary rocks and include anti clinal domes and fault traps. Other examples of structural traps occur, including traps associated with salt plugs. Stratigraphic traps occur where there is a permeability barrier caused by the variation in sedimentary rock types.

5. Combination traps are often formed when folded or faulted reservoirs are overlain unconformably by shales, which act as a seal. The Brent field is an excellent example. About 78% of the world's crude oil resources are held in structural traps, 13% in stratigraphic traps and 9% in combination traps.

6. Geophysical techniques that allow whole regions to be surveyed are relatively inexpensive compared with drilling and detailed surveys, but locate only broad areas which might be suitable for exploration. Gravity surveys can be used to locate sedimentary basins because substantial volumes of sedimentary of sediments are characterised by lows in the Earth's gravitational field. Sedimentary basins are also characteristically areas of uniform geomagnetism, whereas igneous rocks and old metamorphic basement rocks often have a highly variable magnetic structure.

7. The main method of determining whether an area has traps that may contain petroleum is through seismic surveying. Seismic sections provide a continuous survey of sedimentary sequences, major fault locations, and other structural information. Once detected, a potential trap can be mapped in detail using 3D

seismic surveys and evaluated by parts of the reservoir, the porosity and permeability of the reservoir rock have been determined, the volume of oil and gas that can be recovered from the field can be estimated

8. Primary recovery methods produce at best only 30% of the reserve. This can be boosted to 40-50% by secondary recovery techniques of pumping water and gas under pressure into the reservoir. Tertiary or enhanced recovery is intended to increase recovery still further, mainly by the injection of detergents into the reservoir to reduce viscosity. Another exciting prospect is the use of bacteria to produce gas or solvents within the reservoir. Any improvements in the percentage recovery will have an important bearing on the estimates of total recoverable reserves.

9. The most significant local environment risks from petroleum production come from accidental spillages and transportation

10. Petroleum plays hold the key to resource evaluation. Once a play has been discovered, the elements of that play can be assessed and the likely petroleum reserves can be calculated. If our current petroleum reserve calculations turn out to be inaccurate, it is most likely to be because significant plays have not yet been discovered.

11. The oil and gas fields in the North Sea are mainly Permian (gas) and early Tertiary (oil) reserves. The source of the gas in the southern North Sea basin is the carboniferous coals, and the Jurassic Kimmeridge shales are the source rocks for oil and gas in the northern North Sea basin. Some small gas and oilfields have been discovered onshore in Britain.

12. The UK reserves in the North Sea are minute compared with those in the Middle East which has 66% of the world proven reserves of crude oil. Ideal conditions prevailed in the Middle East during the Mesozoic – Cenozoic for the deposition of enormous volumes of source rocks which underwent maturation after the formation of numerous traps..

13. In 1993, the world had reserves of 137 billion tonnes of oil which at 1993 rates of production would last until the year 2036, and 142 trillion cubic meters of deep gas which at 1993 rates of production would last until the year 2058

14. Large amounts of oil and gas are locked into oil sands and gas hydrates, but they do not yet constitute an economic resource.

Section 5

1. The R/P ratio does not vary simply year on year. To assess lifetimes of fuel reserves more accurately, we need to look at changes in R/P ratios over time, and relate those changes to the factors that moderate discovery and production.

2. As long as new prospects exist, petroleum R/P ratios are expected to remain roughly constant. The limits of petroleum resources will not be reached until all the world's sedimentary basins have been fully explored. With present demands and incentives, the world has a "rolling cushion" of some thirty years of oil beyond the time limits of exploration.

3. Burning hydrocarbons in air releases heat, water and carbon dioxide. The more complex hydrocarbons in petrol produce more CO_2 and less water than the simple ones in natural gas.

4. Impurities such as sulphur, nitrogen and ash occur in varying amounts in fossil fuels. Burning the fuel also liberates sulphur dioxide and nitrogen oxides

5. Three effects of burning fossil fuels currently cause much environmental concern; acid rain, ozone depletion and global warming through enhanced greenhouse effect.

6. By the action of sunlight and catalysts, SO_2 in the atmosphere is turned into first sulphurous acid (H_2SO_3) and the sulphuric acid (H_2SO_4) which are soluble in atmospheric water to produce acid rain. NO_x emissions also react with components of the atmosphere, and form acid rain by generating nitrous and nitric acid solutions. Acid rain damages plants and animals, and poisons water.

7. Ozone is naturally produced by the action of sunlight on oxygen in the upper atmosphere. Ozone formation and destruction are parts of a naturally balanced cycle. Stratospheric ozone absorbs ultraviolet radiation and prevents it from reaching the ground, where it can cause sunburn, skin cancer and eye problems. NOx from burning fossil fuels and chlorine can destroy ozone permanently. Ozone close to the ground from the action of light on NOx from car exhausts, and can damage plants, trigger asthma and bronchitis, and contribute to the formation of acid rain.

8. There is a natural greenhouse effect that already keeps the earths surface $33^{o}C$ warmer than it otherwise might be. Comparatively high atmospheric concentrations of waste gas, notably CO_2, from burning fossil fuels and other human activity are enhancing the greenhouse effect and appear to be causing global warming. An intermediate reduction of CO_2 emissions from human activities of over 60% is required if we are to stabilise atmospheric CO2 at present day levels.