EnergyPro-practice-1-extended *[183 marks]*

Two renewable energy sources are solar and wind.

1a. Describe the difference between photovoltaic cells and solar heating panels. *[1 mark]*

1b. A solar farm is made up of photovoltaic cells of area 25 000 m^2. The average solar intensity falling on the farm is 240 W m^{-2} and the average power output of the farm is 1.6 MW. Calculate the efficiency of the photovoltaic cells. *[2 marks]*

An alternative generation method is the use of wind turbines.

The following data are available:

Length of turbine blade = 17 m
Density of air = 1.3 kg m^{-3}
Average wind speed = 7.5 m s^{-1}

1c. Determine the minimum number of turbines needed to generate the same power as the solar farm. *[3 marks]*

1d. Explain **two** reasons why the number of turbines required is likely to be greater than your answer to (c)(i). *[2 marks]*

2a. Outline, with reference to energy changes, the operation of a pumped storage hydroelectric system. *[2 marks]*

2b. The hydroelectric system has four 250 MW generators. The specific energy available from the water is 2.7 kJ kg^{-1}. Determine the maximum time for which the hydroelectric system can maintain full output when a mass of 1.5 x 10^{10} kg of water passes through the turbines. *[2 marks]*

2c. Not all the stored energy can be retrieved because of energy losses in the system. Explain **one** such loss. *[1 mark]*

2d. At the location of the hydroelectric system, an average intensity of 180 W m^{-2} arrives at the Earth's surface from the Sun. Solar photovoltaic (PV) cells convert this solar energy with an efficiency of 22 %. The solar cells are to be arranged in a square array. Determine the length of one side of the array that would be required to replace the hydroelectric system. *[2 marks]*

This question is about energy sources.

A small island is situated in the Arctic. The islanders require an electricity supply but have no fossil fuels on the island. It is suggested that wind generators should be used in combination with power stations using either oil or nuclear fuel.

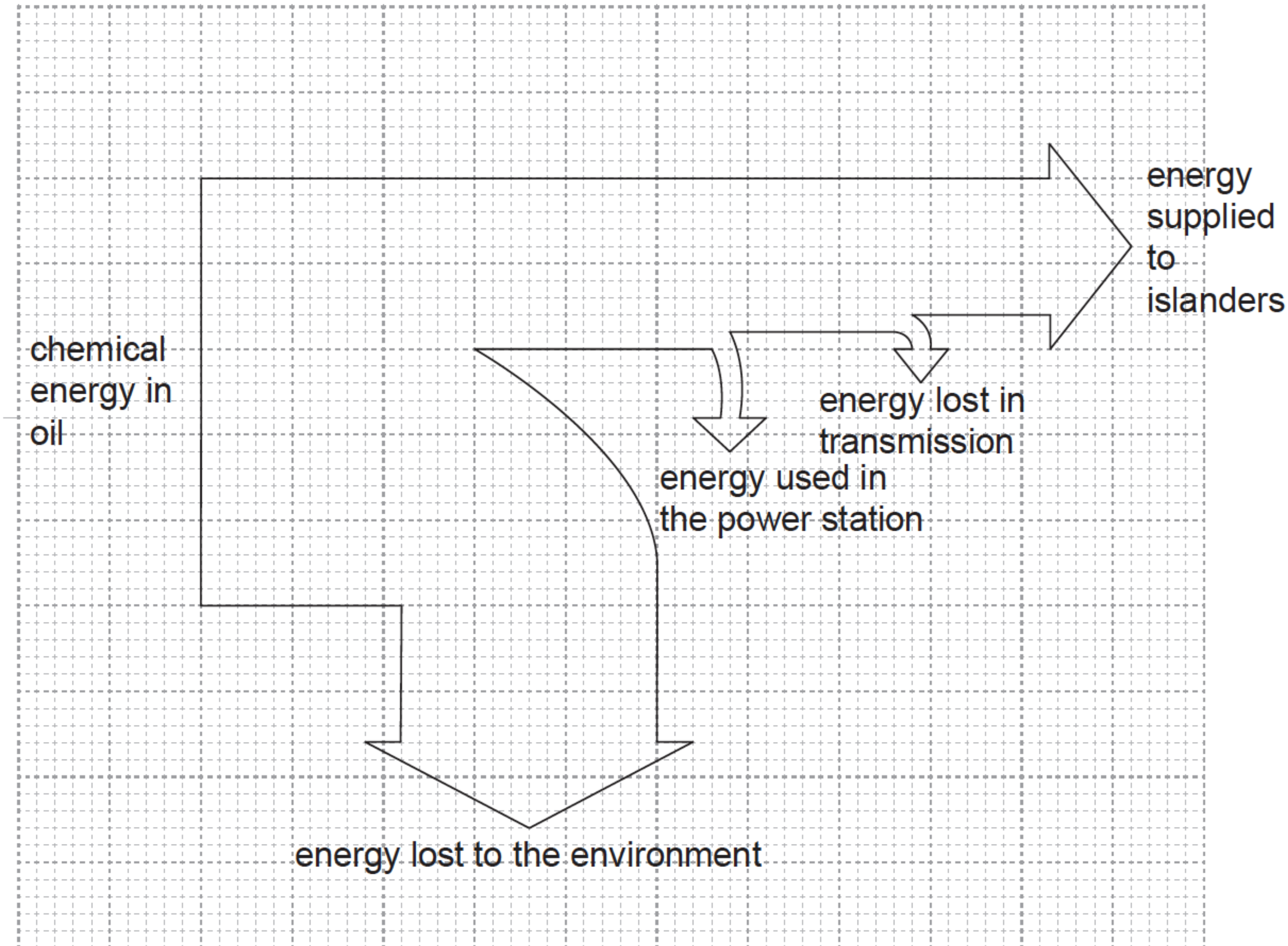
3a. Suggest the conditions that would make use of wind generators in combination with either oil or nuclear fuel suitable for the islanders. *[3 marks]*

3b. Conventional horizontal-axis wind generators have blades of length 4.7m. The average wind speed on the island is $7.0ms^{-1}$ and the average air density is $1.29kgm^{-3}$. *[5 marks]*

(i) Deduce the total energy, in GJ, generated by the wind generators in one year.

(ii) Explain why less energy can actually be generated by the wind generators than the value you deduced in (b)(i).

3c. The energy flow diagram (Sankey diagram) below is for an oil-fired power station that the islanders might use. *[4 marks]*



(i) Determine the efficiency of the power station.

(ii) Explain why energy is wasted in the power station.

(iii) The Sankey diagram in (c) indicates that some energy is lost in transmission. Explain how this loss occurs.

3d. The emissions from the oil-fired power station in (c) are likely to increase global warming by the enhanced greenhouse effect. *[3 marks]*

Outline the mechanism by which greenhouse gases contribute to global warming.

3e. Nuclear fuel must be enriched before it can be used. Outline why fuel enrichment is needed. *[2 marks]*

3f. The nuclear equation below shows one of the possible fission reactions in a nuclear reactor. *[3 marks]*

$$\left({}^{1}_{0}\mathrm{n} + {}^{\cdots}_{92}\mathrm{U} \rightarrow {}^{92}_{\cdots}\mathrm{Kr} + {}^{141}_{56}\mathrm{Ba} + \ldots {}^{1}_{0}\mathrm{n}\right)$$

Identify the missing numbers in the equation.

3g. A nuclear reactor requires both control rods and a moderator to operate. Outline, with reference to neutrons, **one** similarity and **two** differences in the function of each of these components. *[3 marks]*

This question is in two parts. **Part 1** is about renewable energy. **Part 2** is about nuclear energy and radioactivity.

Part 1 Renewable energy

A small coastal community decides to use a wind farm consisting of five identical wind turbines to generate part of its energy. At the proposed site, the average wind speed is 8.5ms^{-1} and the density of air is 1.3kgm^{-3}. The maximum power required from the wind farm is 0.75 MW. Each turbine has an efficiency of 30%.

4a. (i) Determine the diameter that will be required for the turbine blades to achieve the maximum power of 0.75 MW. *[8 marks]*

(ii) State **one** reason why, in practice, a diameter larger than your answer to (a)(i) is required.

(iii) Outline why the individual turbines should not be placed close to each other.

(iv) Some members of the community propose that the wind farm should be located at sea rather than on land. Evaluate this proposal.

4b. Currently, a nearby coal-fired power station generates energy for the community. Less coal will be burnt at the power station if the wind farm is constructed. *[7 marks]*

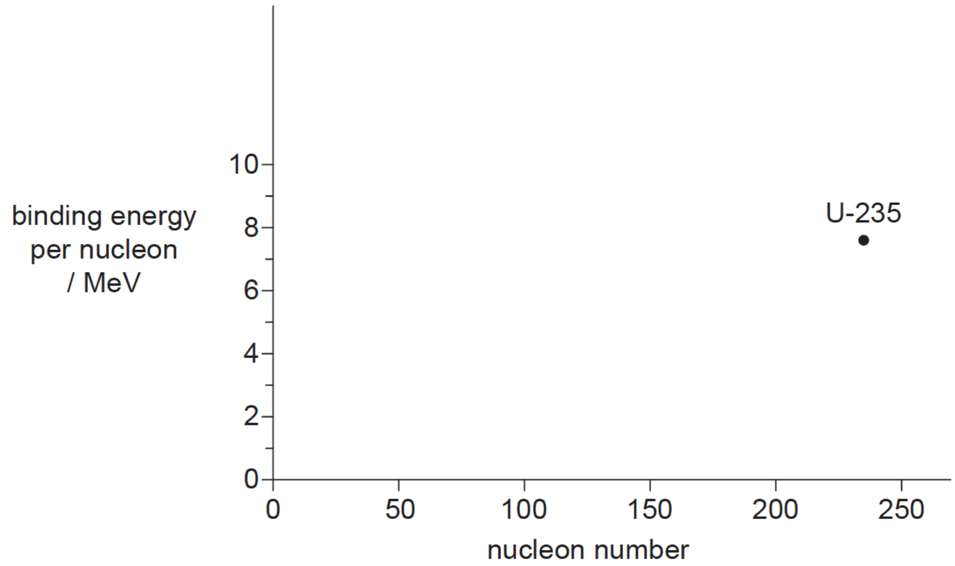
(i) The energy density of coal is 35 MJ kg^{-1}. Estimate the minimum mass of coal that can be saved every hour when the wind farm is producing its full output.

(ii) One advantage of the reduction in coal consumption is that less carbon dioxide will be released into the atmosphere. State **one** other advantage and **one** disadvantage of constructing the wind farm.

(iii) Suggest the likely effect on the Earth's temperature of a reduction in the concentration of atmospheric greenhouse gases.

Part 2 Nuclear energy and radioactivity

The graph shows the variation of binding energy per nucleon with nucleon number. The position for uranium-235 (U-235) is shown.



4c. State what is meant by the binding energy of a nucleus. *[1 mark]*

4d. (i) On the axes, sketch a graph showing the variation of nucleon number with the binding energy per nucleon. *[5 marks]*

(ii) Explain, with reference to your graph, why energy is released during fission of U-235.

4e. U-235 $\left({}^{235}_{92}\mathrm{U}\right)$ can undergo alpha decay to form an isotope of thorium (Th). *[4 marks]*

(i) State the nuclear equation for this decay.

(ii) Define the term *radioactive half-life*.

(iii) A sample of rock contains a mass of 5.6 mg of U-235 at the present day. The half-life of U-235 is 7.0×10^8 years. Calculate the initial mass of the U-235 if the rock sample was formed 2.1×10^9 years ago.

This question is about a tidal power station.

A tidal power station is built for a coastal town. Sea water is stored in a tidal basin behind a dam at high tide and released in a controlled manner between high tides, so that it passes through turbines to generate electricity.

The following data are available.

Difference between high and low tide water level = 1.8m
Density of sea water = 1.1×10^{3}kgm^{-3}
Surface area of basin = 1.4×10^{5}m^{2}
Overall efficiency of power station = 24%

5a. (i) Show that the mass of sea water released between successive high and low tides is about 2.8×10^{8} kg. *[5 marks]*

(ii) Calculate the electrical energy produced between successive high and low tides.

5b. (i) Identify **one** mechanism through which energy is transferred to the surroundings during the electricity generation process. *[2 marks]*

(ii) State why the energy transferred to the surroundings is said to be degraded.

This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	7.0×10^{8} m
Surface temperature of Sun	T	5.8×10^{3} K
Distance from Sun to Earth	d	1.5×10^{11} m
Stefan-Boltzmann constant	σ	5.7×10^{-8} W m^{-2} K^{-4}

6a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

6b. Deduce that the solar power incident per unit area at distance d from the Sun is given by *[2 marks]*

$$\frac{\sigma R^2 T^4}{d^2}$$

6c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

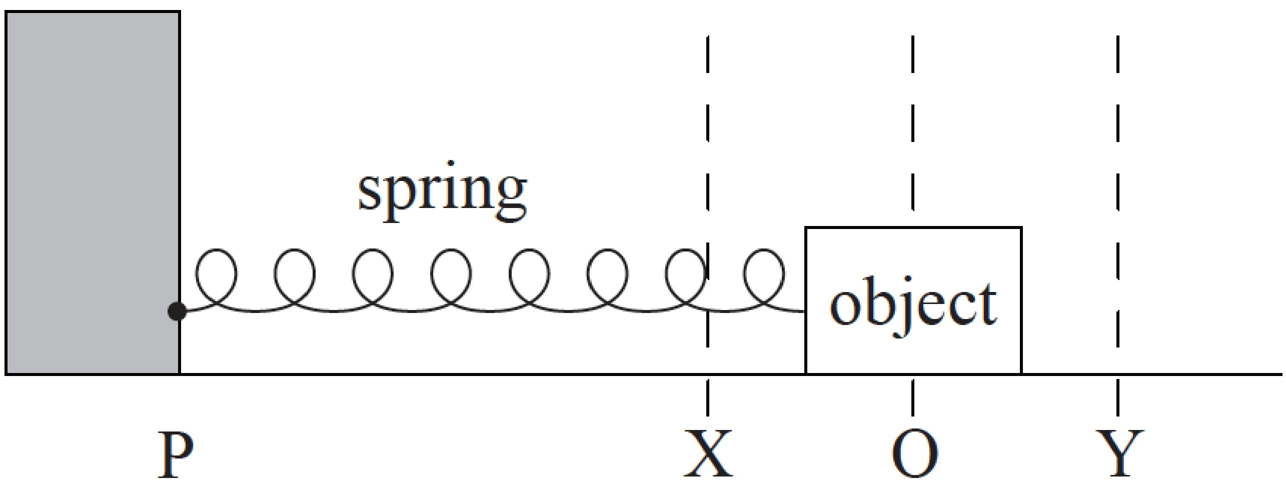
6d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

6e. The average power absorbed per unit area at the Earth's surface is 240Wm^{-2}. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

6f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

Part 2 A mass on a spring

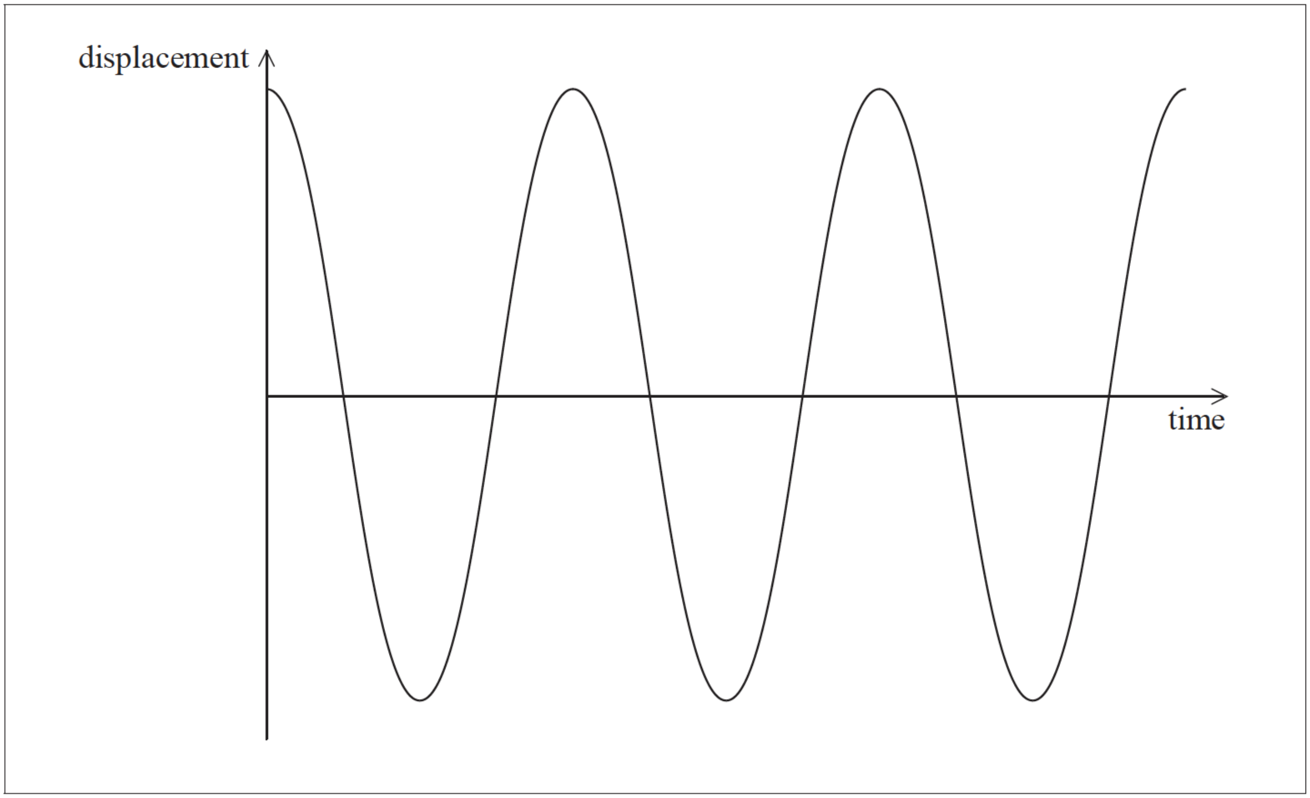
An object is placed on a frictionless surface and attached to a light horizontal spring.



The other end of the spring is attached to a stationary point P. Air resistance is negligible. The equilibrium position is at O. The object is moved to position Y and released.

6g. Outline the conditions necessary for the object to execute simple harmonic motion. *[2 marks]*

6h. The sketch graph below shows how the displacement of the object from point O varies with time over three time periods. *[4 marks]*



(i) Label with the letter A a point at which the magnitude of the acceleration of the object is a maximum.

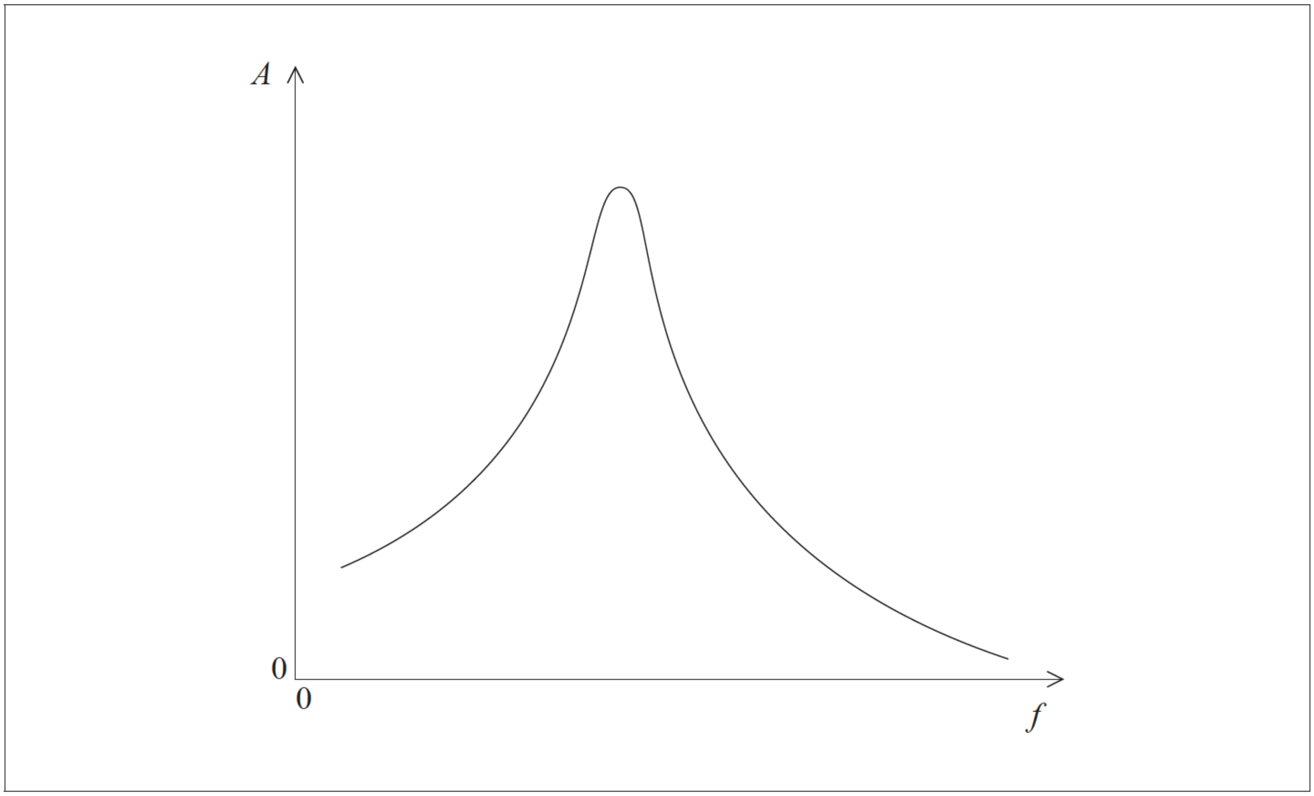
(ii) Label with the letter V a point at which the speed of the object is a maximum.

(iii) Sketch on the same axes a graph of how the displacement varies with time if a **small** frictional force acts on the object.

6i. Point P now begins to move from side to side with a small amplitude and at a variable driving frequency *f*. The frictional force is still small. *[4 marks]*

At each value of *f*, the object eventually reaches a constant amplitude *A*.

The graph shows the variation with *f* of *A*.



(i) With reference to resonance and resonant frequency, comment on the shape of the graph.

(ii) On the same axes, draw a graph to show the variation with *f* of *A* when the frictional force acting on the object is increased.

This question is about the use of energy resources.

7a. State the difference between renewable and non-renewable energy sources. *[1 mark]*

Electrical energy is obtained from tidal energy at La Rance in France.

Water flows into a river basin from the sea for six hours and then flows from the basin back to the sea for another six hours. The water flows through turbines and generates energy during both flows.

The following data are available.

Area of river basin $= 22\ \mathrm{km}^2$

Change in water level of basin over six hours $= 6.0\ \mathrm{m}$

Density of water $= 1000\ \mathrm{kg\,m}^{-3}$

7b. (i) The basin empties over a six hour period. Show that about $6000\ \mathrm{m}^3$ of water flows through the turbines every second. *[10 marks]*

(ii) Show that the average power that the water can supply over the six hour period is about 0.2 GW.

(iii) La Rance tidal power station has an energy output of $5.4 \times 10^8\ \mathrm{kW\,h}$ per year. Calculate the overall efficiency of the power station. Assume that the water can supply 0.2 GW at all times.

Energy resources such as La Rance tidal power station could replace the use of fossil fuels. This may result in an increase in the average albedo of Earth.

(iv) State **two** reasons why the albedo of Earth must be given as an average value.

Nuclear reactors are used to generate energy. In a particular nuclear reactor, neutrons collide elastically with carbon-12 nuclei $\left({}^{12}_{6}\mathrm{C}\right)$ that act as the moderator of the reactor. A neutron with an initial speed of $9.8 \times 10^6\ \mathrm{m\,s}^{-1}$ collides head-on with a stationary carbon-12 nucleus. Immediately after the collision the carbon-12 nucleus has a speed of $1.5 \times 10^6\ \mathrm{m\,s}^{-1}$.

7c. (i) State the principle of conservation of momentum. *[10 marks]*

(ii) Show that the speed of the neutron immediately after the collision is about $8.0 \times 10^6\ \mathrm{m\,s}^{-1}$.

(iii) Show that the fractional change in energy of the neutron as a result of the collision

is about 0.3.

(iv) Estimate the minimum number of collisions required for the neutron to reduce its initial energy by a factor of 10^6.

(v) Outline why the reduction in energy is necessary for this type of reactor to function.

Part 2 Melting of the Pobeda ice island

8a. The Pobeda ice island forms regularly when icebergs run aground near the Antarctic ice shelf. The "island", which consists of a slab of pure ice, breaks apart and melts over a period of decades. The following data are available. *[8 marks]*

Typical dimensions of surface of island = 70 km × 35 km
Typical height of island = 240 m
Average temperature of the island = –35°C
Density of sea ice = 920 kg m^{-3}
Specific latent heat of fusion of ice = 3.3×10^{5} J kg^{-1}
Specific heat capacity of ice = 2.1×10^{3} J $kg^{-1}K^{-1}$

(i) Distinguish, with reference to molecular motion and energy, between solid ice and liquid water.

(ii) Show that the energy required to melt the island to form water at 0°C is about 2×10^{20} J. Assume that the top and bottom surfaces of the island are flat and that it has vertical sides.

(iii) The Sun supplies thermal energy at an average rate of 450 W m^{-2} to the surface of the island. The albedo of melting ice is 0.80. Determine an estimate of the time taken to melt the island assuming that the melted water is removed immediately and that no heat is lost to the surroundings.

8b. Suggest the likely effect on the average albedo of the region in which the island was floating as a result of the melting of the Pobeda ice island. *[2 marks]*

This question is about the greenhouse effect.

The following data are available for use in this question:

Quantity	Symbol	Value
Power emitted by the Sun	P	3.8×10^{26} W
Distance from the Sun to the Earth	d	1.5×10^{11} m
Radius of the Earth	r	6.4×10^{6} m
Albedo of the Earth's atmosphere	α	0.31
Stefan–Boltzmann constant	σ	5.7×10^{-8} $Wm^{-2}K^{-4}$

9a. Explain why the power absorbed by the Earth is *[3 marks]*

$$\frac{P}{4\pi d^2}\times(1-\alpha)\times\pi r^2$$

9b. The equation in (a) leads to the following expression which can be used to predict the Earth's average surface temperature *T*. *[4 marks]*

$$T = \sqrt[4]{\frac{(1-\alpha)\,P}{16\pi\sigma d^2}}$$

(i) Calculate the predicted temperature of the Earth.

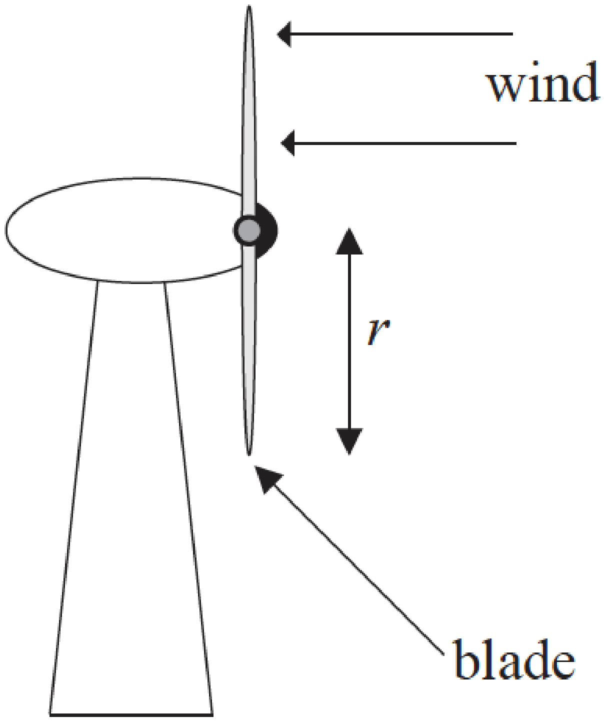
(ii) Explain why the actual average surface temperature of the Earth is in fact higher than the answer to (b)(i).

This question is in **two** parts. **Part 1** is about wind power. **Part 2** is about radioactive decay.

Part 1 Wind power

10a. Outline in terms of energy changes how electrical energy is obtained from the energy of wind. *[2 marks]*

10b. Air of density ρ and speed v passes normally through a wind turbine of blade length r as shown below. *[5 marks]*



(i) Deduce that the kinetic energy per unit time of the air incident on the turbine is

$$\frac{1}{2}\pi\rho r^2 v^3$$

(ii) State **two** reasons why it is impossible to convert all the available energy of the wind to electrical energy.

10c. Air is incident normally on a wind turbine and passes through the turbine blades without changing direction. The following data are available. *[3 marks]*

Density of air entering turbine = 1.1 kg m^{-3}
Density of air leaving turbine = 2.2 kg m^{-3}
Speed of air entering turbine = 9.8 m s^{-1}
Speed of air leaving turbine = 4.6 m s^{-1}
Blade length = 25 m

Determine the power extracted from the air by the turbine.

10d. A wind turbine has a mechanical input power of 3.0×10^5W and generates an electrical power output of 1.0×10^5W. On the grid below, construct and label a Sankey diagram for this wind turbine. *[3 marks]*

10e. Outline **one** advantage and **one** disadvantage of using wind turbines to generate electrical energy, as compared to using fossil fuels. *[2 marks]*

Advantage:

Disadvantage:

This question is in **two** parts. **Part 1** is about solar power and climate models. **Part 2** is about gravitational fields and electric fields.

Part 1 Solar power and climate models

11a. Distinguish, in terms of the energy changes involved, between a solar heating panel and a photovoltaic cell. *[2 marks]*

11b. State an appropriate domestic use for a *[2 marks]*

(i) solar heating panel.

(ii) photovoltaic cell.

11c. The radiant power of the Sun is 3.90×10^{26} W. The average radius of the *[3 marks]*
Earth's orbit about the Sun is 1.50×10^{11} m. The albedo of the atmosphere is 0.300 and it may be assumed that no energy is absorbed by the atmosphere.

Show that the intensity incident on a solar heating panel at the Earth's surface when the Sun is directly overhead is 966 Wm^{-2}.

11d. Show, using your answer to (c), that the average intensity incident on the Earth's surface is 242 Wm^{-2}. *[3 marks]*

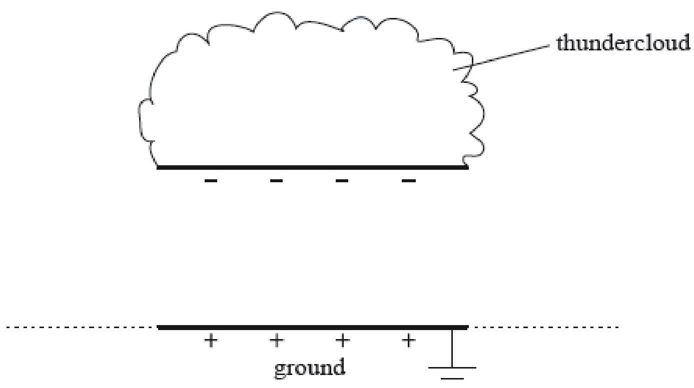
11e. Assuming that the Earth's surface behaves as a black-body and that no energy is absorbed by the atmosphere, use your answer to (d) to show that the average temperature of the Earth's surface is predicted to be 256 K. *[2 marks]*

This question is in **two** parts. **Part 1** is about a lightning discharge. **Part 2** is about fuel for heating.

Part 1 Lightning discharge

12a. Define *electric field strength*. *[2 marks]*

12b. A thundercloud can be modelled as a negatively charged plate that is parallel to the ground. *[3 marks]*



The magnitude of the charge on the plate increases due to processes in the atmosphere. Eventually a current discharges from the thundercloud to the ground.

On the diagram, draw the electric field pattern between the thundercloud base and the ground.

The magnitude of the electric field strength E between two infinite charged parallel plates is given by the expression

$$E = \frac{\sigma}{\varepsilon_0}$$

where σ is the charge per unit area on one of the plates.

A thundercloud carries a charge of magnitude 35 C spread over its base. The area of the base is $1.2 \times 10^7\ \mathrm{m}^2$.

12c. (i) Determine the magnitude of the electric field between the base of the thundercloud and the ground. *[12 marks]*

(ii) State **two** assumptions made in (c)(i).

1.

2.

(iii) When the thundercloud discharges, the average discharge current is 1.8 kA. Estimate the discharge time.

(iv) The potential difference between the thundercloud and the ground before discharge is $2.5 \times 10^8\ \mathrm{V}$. Determine the energy released in the discharge.

Part 2 Fuel for heating

12d. Define the *energy density* of a fuel. *[1 mark]*

A room heater burns liquid fuel and the following data are available.

$$\begin{array}{ll} \text{Density of liquid fuel} & = 8.0 \times 10^2\ \mathrm{kg\,m^{-3}} \\ \text{Energy produced by } 1\ \mathrm{m}^3 \text{ of liquid fuel} & = 2.7 \times 10^{10}\ \mathrm{J} \\ \text{Rate at which fuel is consumed} & = 0.13\ \mathrm{g\,s^{-1}} \\ \text{Latent heat of vaporization of the fuel} & = 290\ \mathrm{kJ\,kg^{-1}} \end{array}$$

12e. (i) Use the data to calculate the power output of the room heater, ignoring the power required to convert the liquid fuel into a gas. *[5 marks]*

(ii) Show why, in your calculation in (b)(i), the power required to convert the liquid fuel into a gas at its boiling point can be ignored.

12f. State, in terms of molecular structure and their motion, **two** differences between a liquid and a gas. *[2 marks]*

1.

2.