EnergyPro-practice-2-ShortA

[186 marks]

This question is in **two** parts. **Part 1** is about Newton's laws and momentum. **Part 2** is about the greenhouse effect.

Part 1 Newton's laws and momentum

1a. State the condition for the momentum of a system to be conserved. *[1 mark]*

1b. A person standing on a frozen pond throws a ball. Air resistance and friction can be considered to be negligible. *[5 marks]*

(i) Outline how Newton's third law and the conservation of momentum apply as the ball is thrown.

(ii) Explain, with reference to Newton's second law, why the horizontal momentum of the ball remains constant whilst the ball is in flight.

1c. The maximum useful power output of a locomotive engine is 0.75 M W. The maximum speed of the locomotive as it travels along a straight horizontal track is 44 m s^{-1}. Calculate the frictional force acting on the locomotive at this speed. *[2 marks]*

1d. The locomotive engine in (c) gives a truck X a sharp push such that X moves along a horizontal track and collides with a stationary truck Y. As a result of the collision the two trucks stick together and move off with speed v. The following data are available. *[4 marks]*

Mass of truck X=3.7×10^3 kg
Mass of truck Y=6.3×10^3 kg
Speed of X just before collision=4.0 m s^{-1}

(i) Calculate v.

(ii) Determine the kinetic energy lost as a result of the collision.

1e. The trucks X and Y come to rest after travelling a distance of 40 m along the horizontal track. Determine the average frictional force acting on X and Y. *[3 marks]*

Part 2 The greenhouse effect

1f. Nuclear fuels, unlike fossil fuels, produce no greenhouse gases. *[5 marks]*

(i) Identify **two** greenhouse gases.

(ii) Discuss, with reference to the mechanism of infrared absorption, why the temperature of the Earth's surface would be lower if there were no greenhouse gases present in the atmosphere.

This question is about alternative energy supplies.

A small island community requires a peak power of 850 kW. Two systems are available for supplying the energy: using wind power or photovoltaic cells.

2a. (i) Outline, with reference to the energy conversions in the machine, the main features of a conventional horizontal-axis wind generator. *[7 marks]*

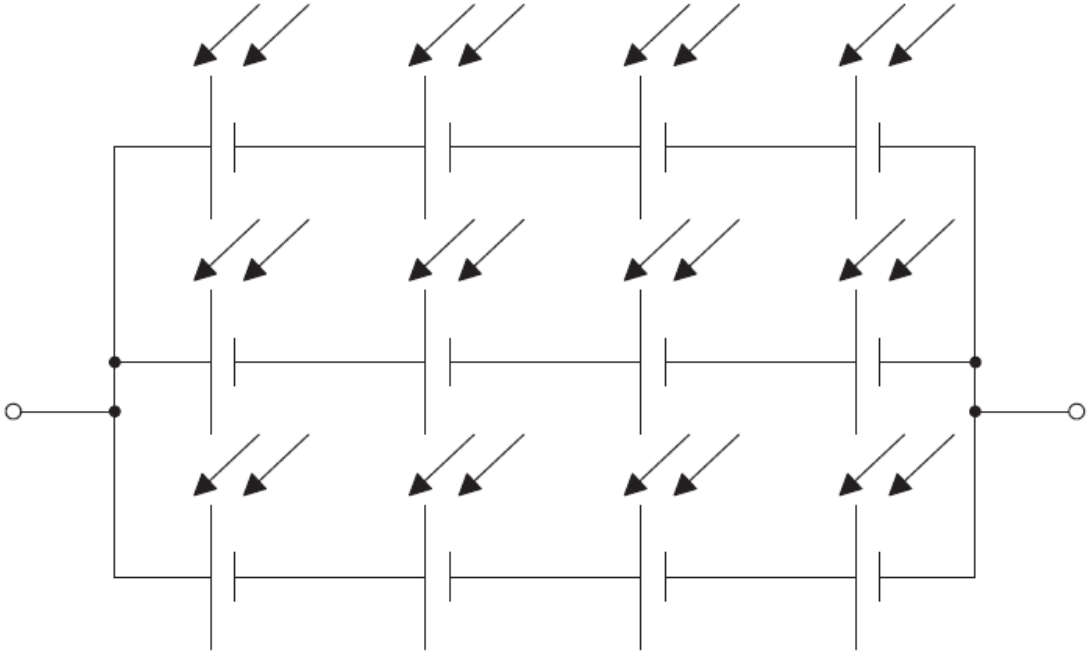
(ii) The mean wind speed on the island is 8.0 ms^{-1}. Show that the maximum power available from a wind generator of blade length 45 m is approximately 2 MW.

Density of air = 1.2 kg m^{3}

(iii) The efficiency of the generator is 24%. Deduce the number of these generators that would be required to provide the islanders with enough power to meet their energy requirements.

2b. Distinguish between photovoltaic cells and solar heating panels. *[2 marks]*

2c. The diagram shows 12 photovoltaic cells connected in series and in parallel to form a module to provide electrical power. *[8 marks]*

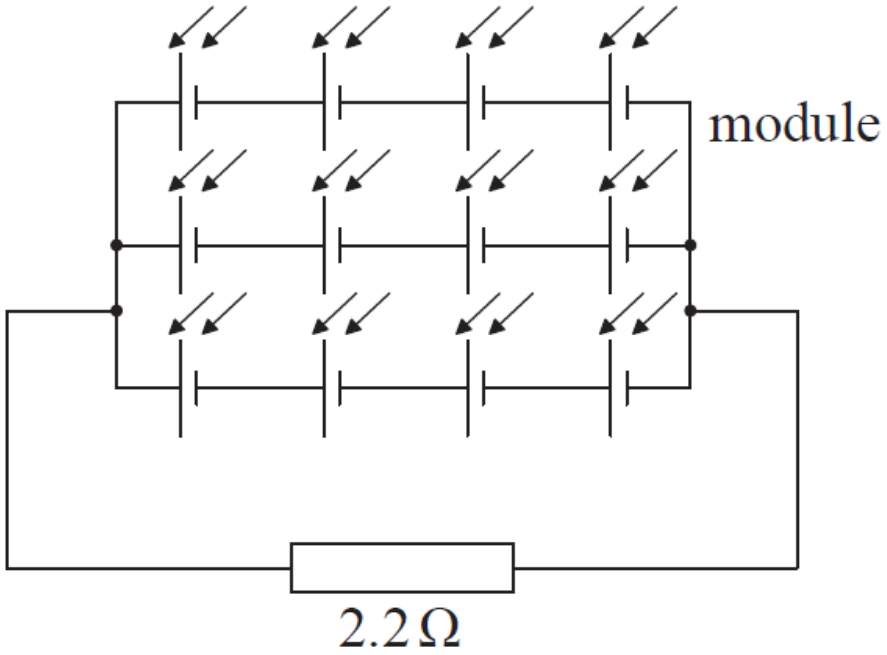


Each cell in the module has an emf of 0.75V and an internal resistance of 1.8Ω.

(i) Calculate the emf of the module.

(ii) Determine the internal resistance of the module.

(iii) The diagram below shows the module connected to a load resistor of resistance 2.2Ω.



Calculate the power dissipated in the load resistor.

(iv) Discuss the benefits of having cells combined in series and parallel within the module.

2d. The intensity of the Sun's radiation at the position of the Earth's orbit (the solar constant) is approximately $1.4\times10^{3}\text{Wm}^{-2}$. *[5 marks]*

(i) Explain why the average solar power per square metre arriving at the Earth is 3.5×10^{2} W.

(ii) State why the solar constant is an approximate value.

(iii) Photovoltaic cells are approximately 20% efficient. Estimate the minimum area needed to supply an average power of 850kW over a 24 hour period.

Part 2 Wind power and the greenhouse effect

3a. A coal-fired power station has a power output of 4.0GW. It has been suggested that a wind farm could replace this power station. Using the data below, determine the area that the wind farm would occupy in order to meet the same power output as the coal-fired power station. *[4 marks]*

Radius of wind turbine blades = 42 m
Area required by each turbine = 5.0×10^{4} m^{2}
Efficiency of a turbine = 30%
Average annual wind speed = 12 m s^{-1}
Average annual density of air = 1.2 kg m^{-3}

3b. Wind power does not involve the production of greenhouse gases. Outline why the surface temperature of the Earth is higher than would be expected without the greenhouse effect. *[3 marks]*

3c. The average solar intensity incident at the surface of the Earth is 238 W m^{-2}. *[5 marks]*

(i) Assuming that the emissivity of the surface of the Earth is 1.0, estimate the average surface temperature if there were no greenhouse effect.

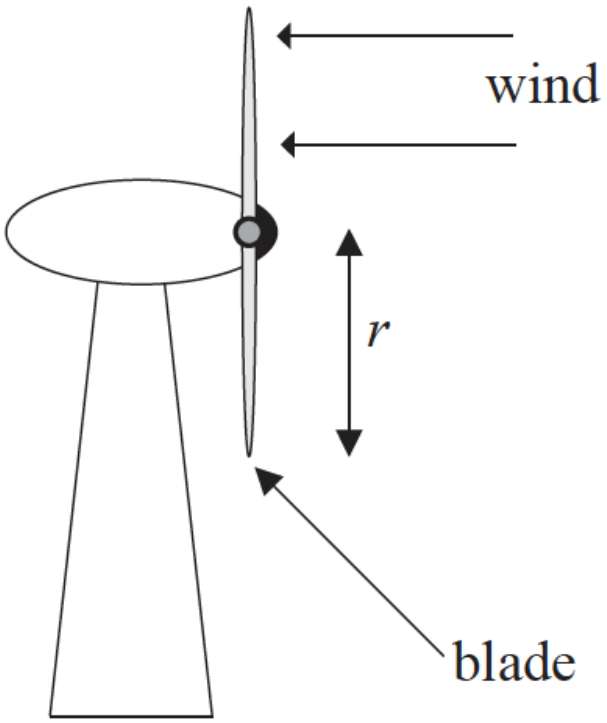
(ii) The enhanced greenhouse effect suggests that in several decades the predicted temperature of the atmosphere will be 250 K. The emissivity of the atmosphere is 0.78. Show that this atmospheric temperature increase will lead to a predicted average Earth surface temperature of 292 K.

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

Part 1 Wind power

4a. Outline in terms of energy changes how electrical energy is obtained from the energy of wind. *[2 marks]*

4b. 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

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

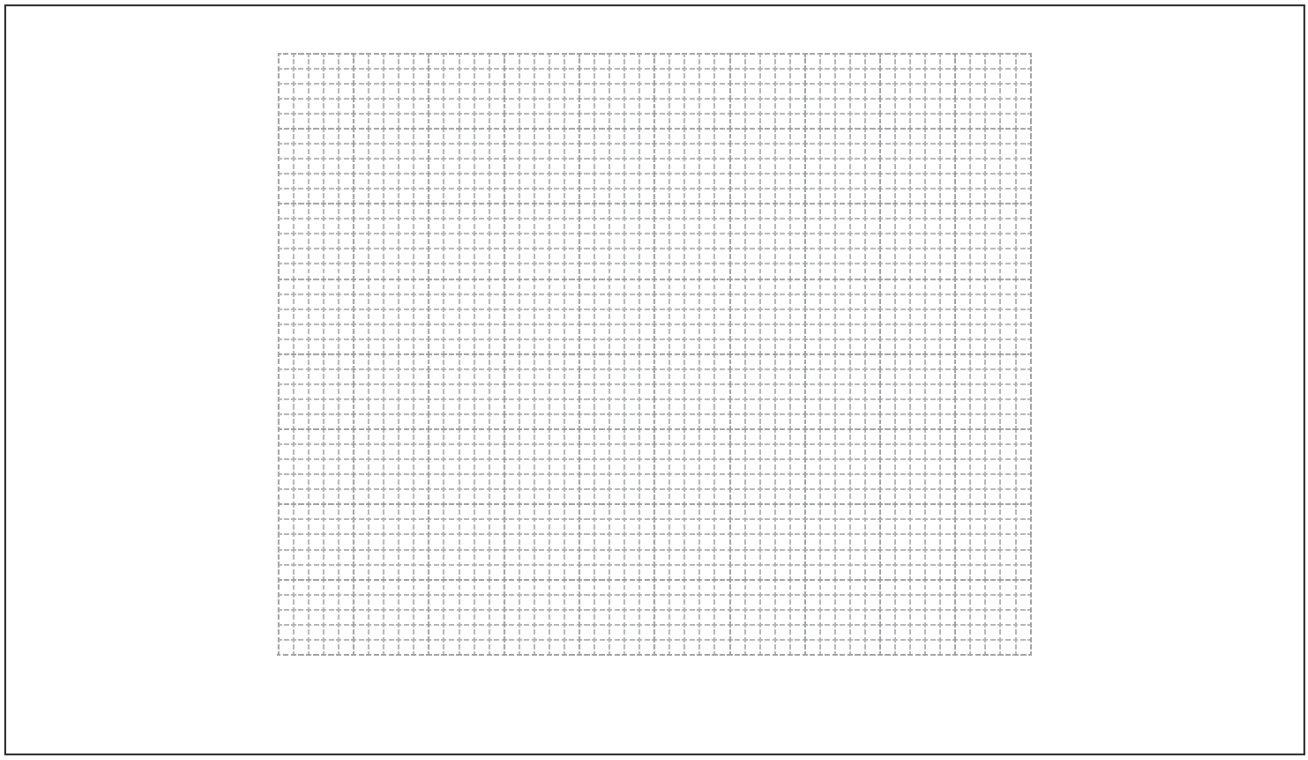
(ii) State **two** reasons why it is impossible to convert all the available energy of the wind to electrical energy.

4c. 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.

4d. 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]*



4e. 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

5a. Distinguish, in terms of the energy changes involved, between a solar heating panel and a photovoltaic cell. *[2 marks]*

5b. State an appropriate domestic use for a *[2 marks]*

(i) solar heating panel.

(ii) photovoltaic cell.

5c. The radiant power of the Sun is 3.90×10^{26} W. The average radius of the 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. *[3 marks]*

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}.

5d. Show, using your answer to (c), that the average intensity incident on the Earth's surface is 242 Wm^{-2}. *[3 marks]*

5e. 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]*

6a. A nuclide of deuterium $\left({}_{1}^{2}\mathrm{H}\right)$ and a nuclide of tritium $\left({}_{1}^{3}\mathrm{H}\right)$ undergo nuclear fusion. *[5 marks]*

(i) Each fusion reaction releases 2.8×10^{-12} J of energy. Calculate the rate, in kg s^{-1}, at which tritium must be fused to produce a power output of 250 MW.

(ii) State **two** problems associated with sustaining this fusion reaction in order to produce energy on a commercial scale.

6b. Tritium is a radioactive nuclide with a half-life of 4500 days. It decays to an isotope of helium. *[3 marks]*

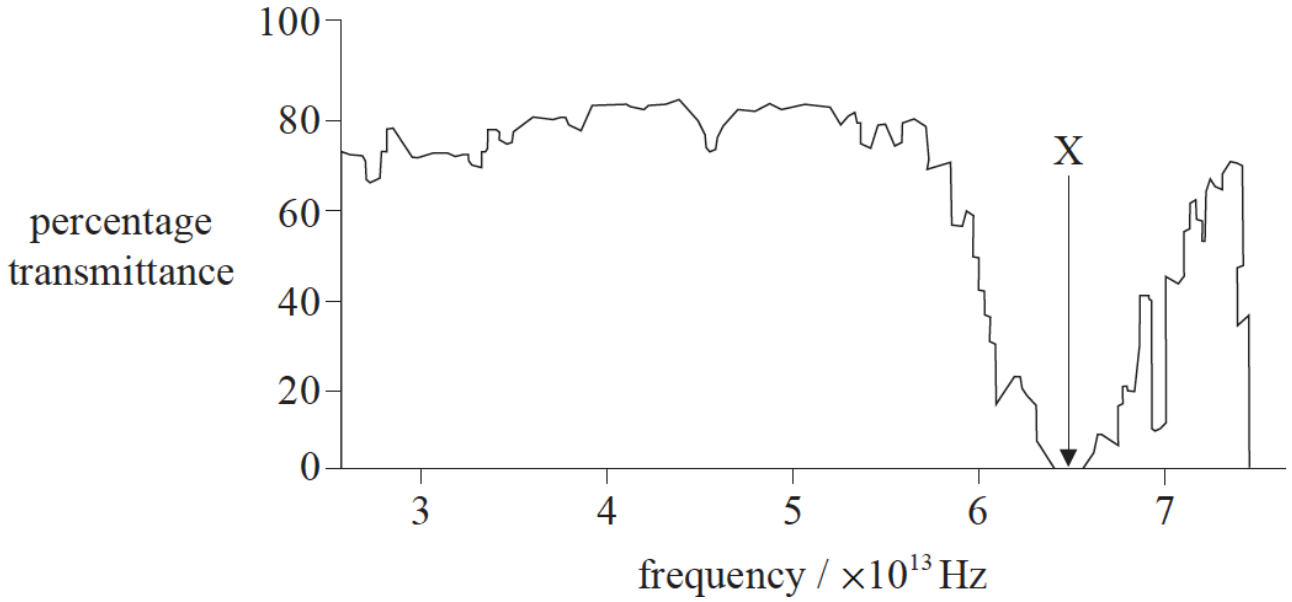
Determine the time at which 12.5% of the tritium remains undecayed.

This question is in **two** parts. **Part 1** is about the greenhouse effect. **Part 2** is about an electric motor.

Part 1 Greenhouse effect

7a. Describe what is meant by the greenhouse effect in the Earth's atmosphere. *[3 marks]*

7b. The graph shows the variation with frequency of the percentage transmittance of electromagnetic waves through water vapour in the atmosphere. *[9 marks]*



(i) Show that the reduction in percentage transmittance labelled X occurs at a wavelength equal to approximately 5 μm.

(ii) Suggest, with reference to resonance, the possible reasons for the sharp reduction in percentage transmittance at a wavelength of 5 μm.

(iii) Explain how the reduction in percentage transmittance, labelled X on the graph opposite, accounts for the greenhouse effect.

(iv) Outline how an increase in the concentration of greenhouse gases in the atmosphere may lead to global warming.

This question is in **two** parts. **Part 1** is about a nuclear reactor. **Part 2** is about simple harmonic oscillations.

Part 1 Nuclear reactor

8a. The reactor produces 24 MW of power. The efficiency of the reactor is 32 % . In the fission of one uranium-235 nucleus 3.2×10^{-11}J of energy is released. *[4 marks]*

Determine the mass of uranium-235 that undergoes fission in one year in this reactor.

8b. Explain what would happen if the moderator of this reactor were to be removed. *[3 marks]*

8c. During its normal operation, the following set of reactions takes place in the reactor. *[3 marks]*

$$^{1}_{0}\mathrm{n} + ^{238}_{92}\mathrm{U} \rightarrow ^{239}_{92}\mathrm{U} \qquad \text{(I)}$$

$$^{239}_{92}\mathrm{U} \rightarrow ^{239}_{93}\mathrm{Np} + ^{0}_{-1}e + \bar{\nu} \qquad \text{(II)}$$

$$^{239}_{93}\mathrm{Np} \rightarrow ^{239}_{94}\mathrm{Pu} + ^{0}_{-1}e + \bar{\nu} \qquad \text{(III)}$$

(i) State the name of the process represented by reaction (II).

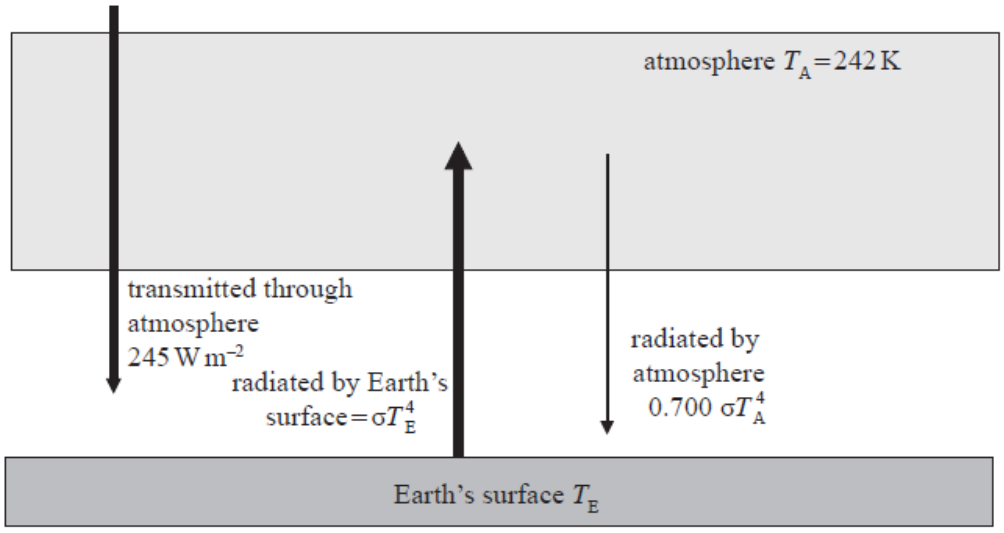
(ii) Comment on the international implications of the product of these reactions.

Part 2 Energy balance of the Earth

9a. The intensity of the Sun's radiation at the position of the Earth is approximately 1400 W m^{-2}. *[2 marks]*

Suggest why the average power received per unit area of the Earth is 350 W m^{-2}.

9b. The diagram shows a simplified model of the energy balance of the Earth's surface. The diagram shows radiation entering or leaving the Earth's surface only. *[4 marks]*



The average equilibrium temperature of the Earth's surface is T_E and that of the atmosphere is T_A = 242K.

(i) Using the data from the diagram, state the emissivity of the atmosphere.

(ii) Show that the intensity of the radiation radiated by the atmosphere towards the Earth's surface is 136Wm^{-2}.

(iii) By reference to the energy balance of the Earth's surface, calculate T_E.

9c. (i) Outline a mechanism by which part of the radiation radiated by the Earth's surface is absorbed by greenhouse gases in the atmosphere. *[7 marks]*

(ii) Suggest why the incoming solar radiation is not affected by the mechanism you outlined in (c)(i).

(iii) Carbon dioxide (CO_2) is a greenhouse gas. State **one** source and **one** sink (object that removes CO_2) of this gas.

This question is in **two** parts. **Part 1** is about power production and global warming. **Part 2** is about electric charge.

Part 1 Power production and global warming

10a. A nuclear power station uses uranium-235 (U-235) as fuel. Outline the *[7 marks]*

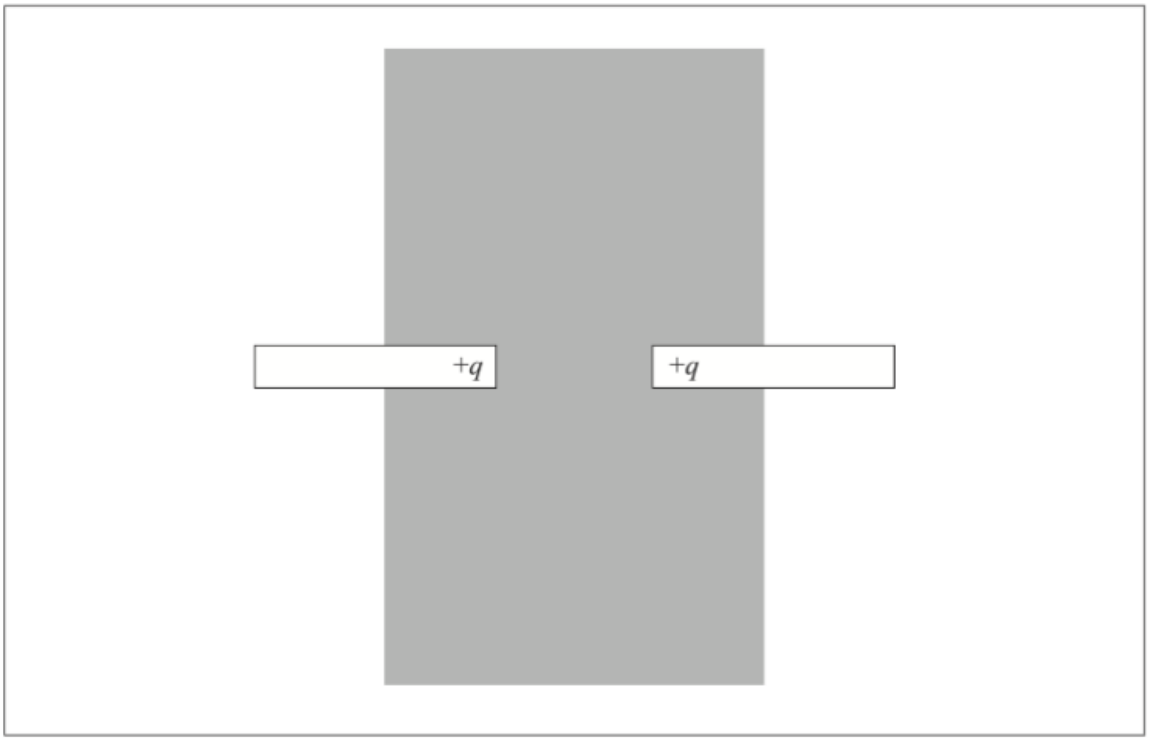
(i) processes and energy changes that occur through which thermal energy is produced.

(ii) role of the heat exchanger of the reactor and the turbine in the generation of electrical energy.

10b. The Drax power station produces an enormous amount of carbon dioxide, a gas classified as a greenhouse gas. Outline, with reference to the vibrational behaviour of molecules of carbon dioxide, what is meant by a greenhouse gas. *[3 marks]*

Part 2 Electric charge

11. Two plastic rods each have a positive charge $+q$ situated at one end. *[2 marks]*
The rods are arranged as shown.



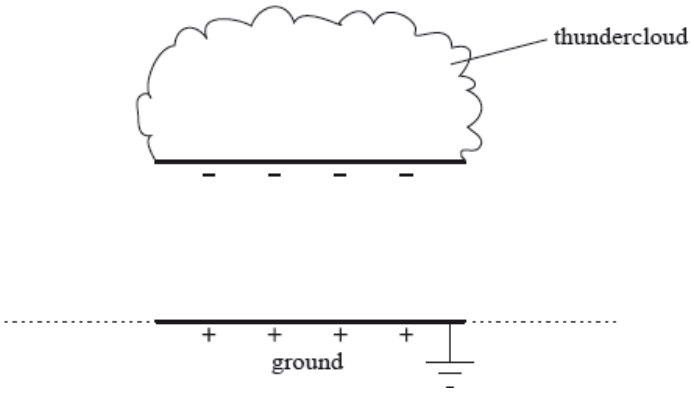
Assume that the charge at the end of each rod behaves as a point charge. Draw, in the shaded area on the diagram, the electric field pattern due to the two charges.

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.

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

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.

This question is in **two** parts. **Part 1** is about the production of energy in nuclear fission. **Part 2** is about collisions.

Part 1 Production of energy in nuclear fission

A possible fission reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + x^{1}_{0}n.$$

13a. (i) State the value of x. *[6 marks]*

(ii) Show that the energy released when one uranium nucleus undergoes fission in the reaction in (a) is about 2.8×10^{-11} J.

$$\begin{aligned}
&\text{Mass of neutron} && = 1.00867\ \text{u} \\
&\text{Mass of U - 235 nucleus} && = 234.99333\ \text{u} \\
&\text{Mass of Kr - 92 nucleus} && = 91.90645\ \text{u} \\
&\text{Mass of Ba - 141 nucleus} && = 140.88354\ \text{u}
\end{aligned}$$

(iii) State how the energy of the neutrons produced in the reaction in (a) is likely to compare with the energy of the neutron that initiated the reaction.

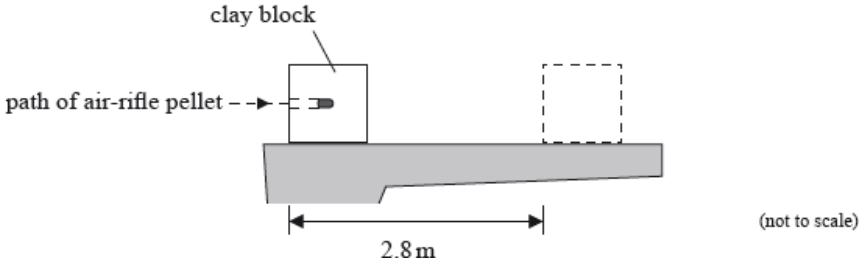
13b. Outline the role of the moderator. *[2 marks]*

13c. A nuclear power plant that uses U-235 as fuel has a useful power output of 16 MW and an efficiency of 40%. Assuming that each fission of U-235 gives rise to 2.8×10^{-11} J of energy, determine the mass of U-235 fuel used per day. *[4 marks]*

Part 2 Collisions

13d. State the principle of conservation of momentum. *[2 marks]*

In an experiment, an air-rifle pellet is fired into a block of modelling clay that rests on a table.



The air-rifle pellet remains inside the clay block after the impact.

As a result of the collision, the clay block slides along the table in a straight line and comes to rest. Further data relating to the experiment are given below.

$$\begin{aligned} &\text{Mass of air - rifle pellet} && = 2.0\ \text{g} \\ &\text{Mass of clay block} && = 56\ \text{g} \\ &\text{Velocity of impact of air - rifle pellet} && = 140\ \text{m s}^{-1} \\ &\text{Stopping distance of clay block} && = 2.8\ \text{m} \end{aligned}$$

13e. (i) Show that the initial speed of the clay block after the air-rifle pellet strikes it is $4.8\ \text{m s}^{-1}$. *[6 marks]*

(ii) Calculate the average frictional force that the surface of the table exerts on the clay block whilst the clay block is moving.

13f. Discuss the energy transformations that occur in the clay block and the air-rifle pellet from the moment the air-rifle pellet strikes the block until the clay block comes to rest. *[3 marks]*

13g. The clay block is dropped from rest from the edge of the table and falls vertically to the ground. The table is 0.85 m above the ground. Calculate the speed with which the clay block strikes the ground. *[2 marks]*

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