GCSE

4781/03-A

SCIENCE B

UNIT 1: Space, Energy and Life

P.M. WEDNESDAY, 5 June 2013

Resource folder (Pre-Release Article)

For use with:

Section B of the Foundation Tier

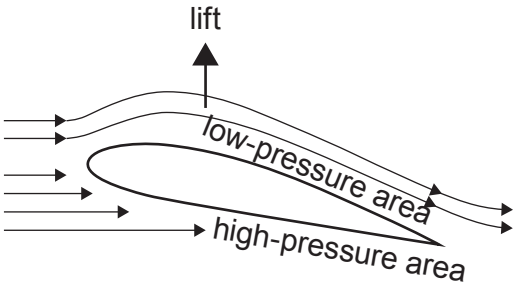
Section A of the Higher Tier

Pre-Release Article - Exploring wind energy

If you place an object like a rotor blade in the path of wind, the wind will push on it, transferring some of its own kinetic energy to the blade. This is how a wind turbine captures energy from the wind.

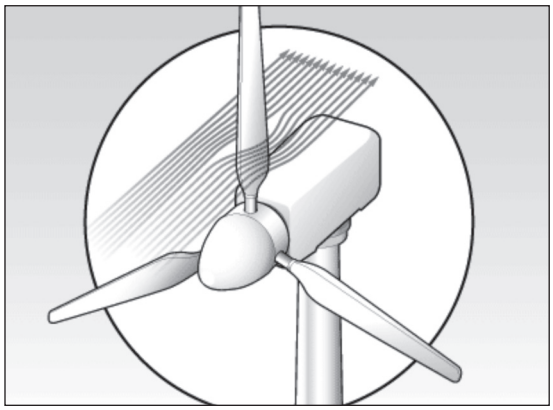
Turbine blades look like aeroplane wings – they use an **aerofoil** design. In an aerofoil, one surface of the blade is rounded, while the other is flat.

Diagram 1



When wind travels over the rounded face of the blade it is forced to move faster than the wind travelling over the flat face of the blade.

Diagram 2



The curved surface ends up with a low-pressure pocket just above it. On the flat side of the blade, the wind is moving slower and creating an area of higher pressure that pushes on the blade.

When it comes to deciding where to place wind turbines, the important factors are:

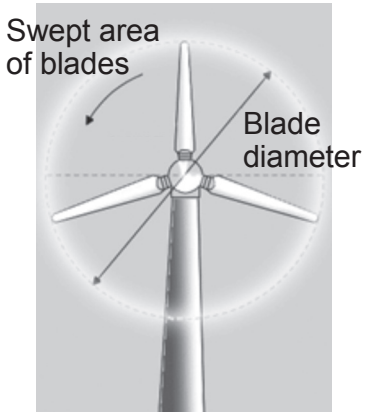
- how windy the location is;
- what the wind speeds are;
- how long those wind speeds last;
- the height of the wind turbine;
- the size of the blades.

The swept area of the blades is given by:

Swept area = π × blade radius^2

where π = 3.14

Diagram 3



The kinetic energy (KE) of wind delivered to a wind turbine every second is given by:

KE/second = ½ × air density × swept area × (wind speed)^3

However, the maximum energy/second that is captured by the turbine from the wind is limited.

Table 1 gives information about five different wind turbines. The blades are **not** identical in shape.

Table 1

Wind turbine	Blade Diameter m	Swept area m^2	Power density m^2/kW	Number of blades	Min wind speed m/s	Nominal wind speed m/s	Max wind speed m/s	Power output max kW
1	35	876	2.66	3	3	13	34	330
2	44	1520	1.69	3	3	14	34	900
3	70	3959	1.72	3	3	14	34	2300
4	90	6361	2.54	3	6	13	25	2500
5	110	9503	2.38	3	6	14	25	4000

Table 2 shows how the **mean wind speed** and **density of air** vary with altitude.

Table 2

Altitude m	Annual mean wind speed m/s	Density of air kg/m^3
12	7.8	1.192
60	9.5	1.187
100	10.3	1.182
160	10.9	1.173
200	11.3	1.167

Table 3 shows how the density of air varies with temperature.

Table 3

Temperature °C	Density of air kg/m^3
+20	1.20
+10	1.25
+5	1.27
0	1.29
–5	1.32

The wind energy industry has been set very ambitious targets for the future. The industry hopes that wind energy can produce **20% of total EU electricity demand by 2020 and 33% by 2030**.

Examiner only

Answer **all** *questions in the spaces provided.*

Use the information in the separate resource booklet to answer the following questions.

1. *(a)* Explain how the shape of the blades causes the wind turbine to turn in the wind. [2]

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(b) Use the information in **Table 1** to answer the questions below.

(i) What is the range of wind speeds in which wind turbine **5** will operate? [1]

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(ii) State the value of the swept area by wind turbine **2**. ..... [1]

(iii) I. State the maximum power output of wind turbine **2**. ..... [1]

II. To give the maximum power output recorded in **Table 1**, the wind power must be 1500 kW.
Calculate the efficiency of wind turbine **2** using the equation: [2]

$$\% \text{ Efficiency} = \frac{\text{useful output power}}{\text{total input power}} \times 100$$

% Efficiency = ...

Examiner only

(c) A wind turbine has a blade diameter of 80 m.

(i) Calculate the swept area of the blades. [2]

Swept area = ... m^2

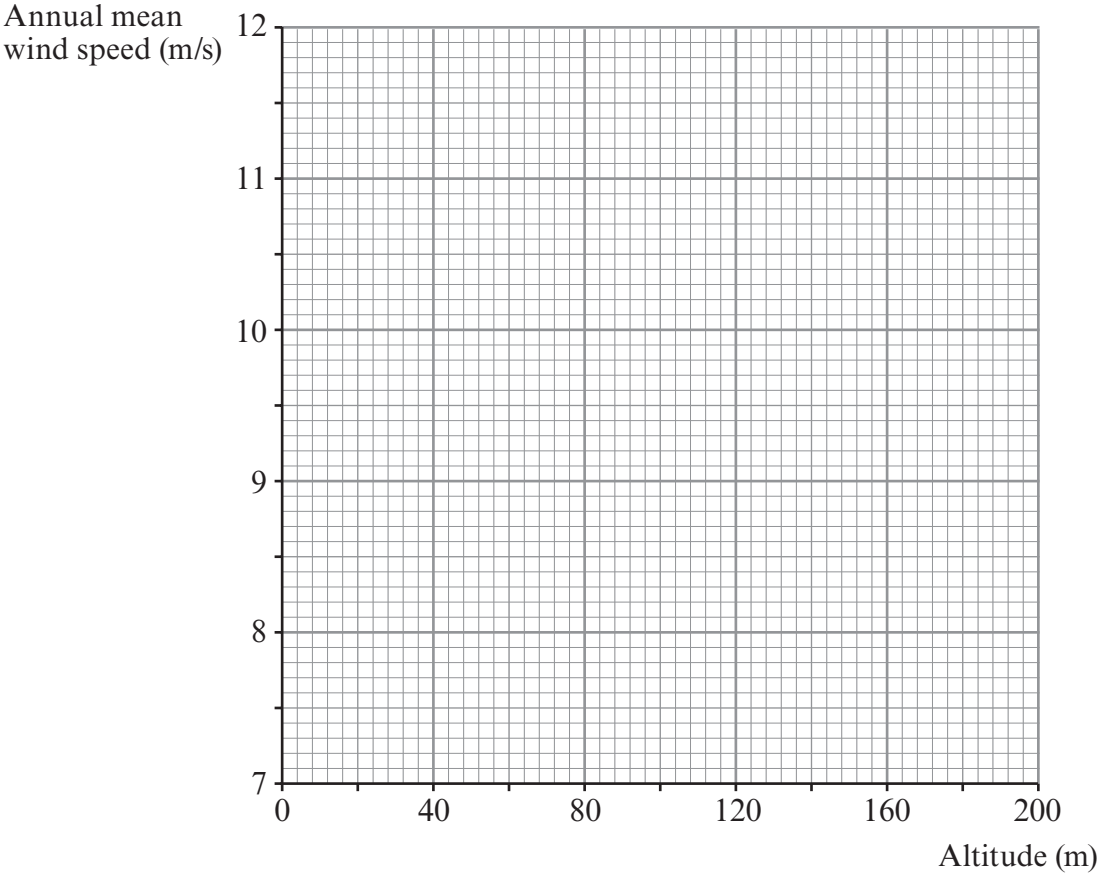
(ii) The turbine is placed at an altitude of 160 m.
Calculate the mean kinetic energy/second delivered to the turbine. [2]
(Use (wind speed)^3 = 1300 m^3/s^3)

Mean kinetic energy/second = ... J/s

Examiner only

(d) (i) Use the information in **Table 2** to answer the questions below.

I. Plot a graph on the grid below to show how **annual mean wind speed** varies with **altitude**. [3]



II. Explain why the maximum power output of a wind turbine is affected by altitude. [2]

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(ii) Use the information in **Table 3** to explain why the power output of the wind turbine will be different in summer and winter. [2]

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Examiner only

(e) Evaluate the benefits and drawbacks of meeting more of the electricity demand with wind power in the future. [6 QWC]

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END OF PAPER

GCSE MARKING SCHEME

SCIENCE B

SUMMER 2013

SECTION B

Question			Answer	Marks
1.	(a)		Different shape surfaces / one side is more curved / flatter which causes difference in air pressure. Two points must be coherently and correctly linked for 2 marks.	1 1
	(b)	(i)	6 – 25 (m/s).	1
		(ii)	1520 (m^2).	1
		(iii)I	900 (kW).	1
		II	Subs of 900 / 1500 %Efficiency = 60.	1 1
	(c)	(i)	Calculation of radius 40 m.	1
			Answer = 5027.2 m^2 / accept 5027. Use of π in calculator gives 5024 Accept range 5024-5027 Use of πr^2 to give 20096 Accept range 20096- 20109	1
		(ii)	Extraction of air density value 1.173. Subs ½ x 1.173 x 5027 (allow ecf) x 1300. Answer of 3 832 836 shown gets both marks.	1 1
	(d)	(i) I	Plots (tolerance +/- 0.5 square) All correct (2), 4 correct (1) Line of best fit (not point to point)	2 1
		II	Power output of a wind turbine depends on wind speed <u>and</u> air density. Both vary with altitude. Points must be correctly and coherently connected for 2 marks.	1 1
		(ii)	Power output varies with air density. which depends on temperature. Points must be correctly and coherently connected for two marks	1 1

Question	Answer	Marks
(e)	**Indicative content:** **Benefits** include references to no fuel costs, renewable resource, no air pollution, no effect on climate. **Drawbacks** include references to variable wind speed, low power outputs, noise pollution, visual pollution. Benefits or drawbacks only max of 3. **5 – 6 marks** The candidate constructs an articulate, integrated account correctly linking relevant points, such as those in the indicative content, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar. **3 – 4 marks** The candidate constructs an account correctly linking some relevant points, such as those in the indicative content, showing some reasoning. The answer addresses the question with some omissions. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar. **1 – 2 marks** The candidate makes some relevant points, such as those in the indicative content, showing limited reasoning. The answer addresses the question with significant omissions. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar. **0 marks** The candidate does not make any attempt or give a relevant answer worthy of credit.	6