Name	Date started	Target end date

GCE AS / A LEVEL — POWER & EFFICIENCY QUESTION PACK

Legacy PH1 · New spec Unit 1 Topic 4b · AS unit, 20% of A-level

REVISE
.wales

PHYSICS — UNIT 1 · POWER & EFFICIENCY

PH1.4 Energy — power, efficiency and large-scale energy generation

Calculating mechanical and electrical power, applying the efficiency = useful / total formula, and reasoning about Sankey diagrams plus large-scale generation / loss analysis.

NEW 2015 SPEC · UNIT 1 TOPIC 4B

Estimated time for entire question pack: ~43 min

Derived from the legacy PH1 paper's pace of 80 marks in 1¼ hours.

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH1 papers (2008 modular spec) that maps onto new-spec Unit 1 Topic 4b (1.4).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

For Examiner's use only

Q	Source	Max	Mark
11	PH1 Jan 09 Q7	7	
12	PH1 Jan 11 Q5	8	
13	PH1 Jan 14 Q7	16	
Total		31	

Power & Efficiency — what the new spec asks

WJEC GCE AS / A Level Physics (from 2015) · Unit 1: Motion, Energy & Matter · Topic 1.4.

Power A

- Define power as rate of doing work / rate of energy transfer.
- Apply P = W/t = Fv for constant force.

Efficiency A

- Efficiency = useful energy out / total energy in (or power-equivalent).
- Express as a ratio or percentage.

Energy generation A

- Sankey diagrams — useful vs wasted energy.
- Power-station efficiency, wind and hydro examples.

Power & Efficiency in one page

Quick-reference notes — revisit before each section.

Power

$P = W/t = E/t$.

Units watt, $W = J\ s^{-1}$.

For constant force on a body moving at v: $P = Fv$.

Electrical power

Equivalent forms for resistive loads.

Useful when comparing electrical and mechanical outputs.

Efficiency

$\eta = E_{useful\ out} / E_{in}$.

Or in power form: $P_{useful\ out} / P_{in}$.

Always ≤ 1; expressed as % usually.

Sankey diagrams

Width of each arrow ∝ amount of energy.

Useful out flows forward; wasted (heat / sound) branches off.

Wasted energy

Friction → heat.

Drag → heat in air.

Resistance → I^2R heating.

Strategy

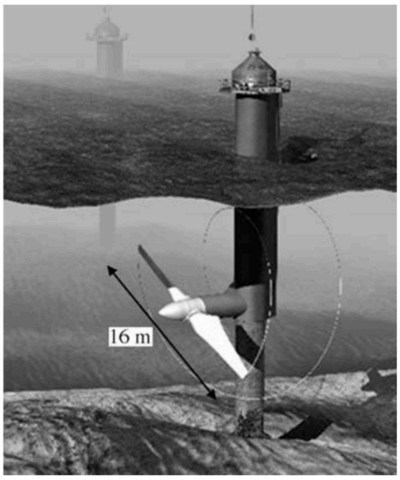
1. Identify total input energy or power.
2. Calculate or read useful output.
3. Divide; convert to % if asked.
4. Check answer < 100%.

Questions begin overleaf.

Section index

Use this index to jump straight to the section you need.

7. Undersea turbines are being developed as a cost-effective means of generating power from tidal streams. Many suitable sites for the location of these turbines have been identified around our coastline. The diagram shows a single turbine of diameter 16 m.



(a) The density of sea water is 1050 kgm^{-3}. Explain what this statement means. [1]

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(b) The following equation gives the power input to the turbine

$$P = \frac{1}{2}\rho A v^3$$

where ρ = density, A = Area swept out by turbine blades, v = velocity of sea water.

(i) Calculate the input power if the turbine is in a tidal stream of velocity 2·5 ms^{-1}. [2]

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(ii) The manufacturers say that they would expect a turbine like this to produce an output of 1000 kW of power when in actual use in a tidal stream of 2·5 ms^{-1}. Use this information and your answer to (b)(i) to calculate the percentage efficiency of the turbine. [1]

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(iii) Explain in terms of the kinetic energy of the water why the turbine is not 100% efficient. [1]

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(iv) Supporters of tidal stream power claim that 'a single tidal turbine would produce the same electrical power as several wind turbines of the same diameter'.

(I) Explain, using the equation on the previous page, why this statement should be true. (Assume that the wind velocity is similar to that of a tidal stream.) [1]

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(II) Suggest one advantage of choosing the tidal stream option. [1]

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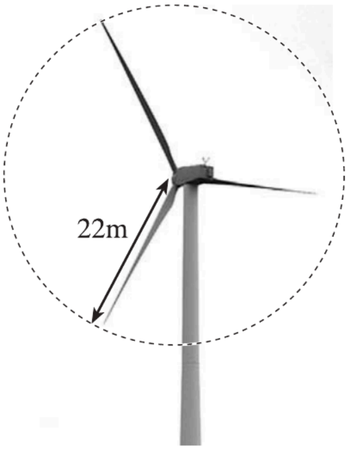
5. A wind turbine, designed to generate electricity, has blades which sweep out an area of radius 22 m. The turbine turns "into the wind" so that the area swept out by the blades is always at right angles to the wind direction.



(i) The volume of air passing through the blades every second can be calculated by considering a cylinder of air incident on the blades. Show that the volume of air passing through the blades in one second is approximately 21000 $m^3 s^{-1}$, when the wind speed is $14 m s^{-1}$. [2]

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(ii) Hence calculate the mass of air passing though the blades every second. [1]
[density of air = $1.2 kg m^{-3}$].

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(iii) The mean speed of the air after it has passed through the blades is $11\,\text{m}\,\text{s}^{-1}$. Calculate the kinetic energy lost by the air per second as it passes through the blades. [3]

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(iv) Assuming that 65% of this 'lost' energy is used to generate electricity, determine the number of turbines that would be needed to produce the same power output as a single 1000 MW coal fired power station. [2]

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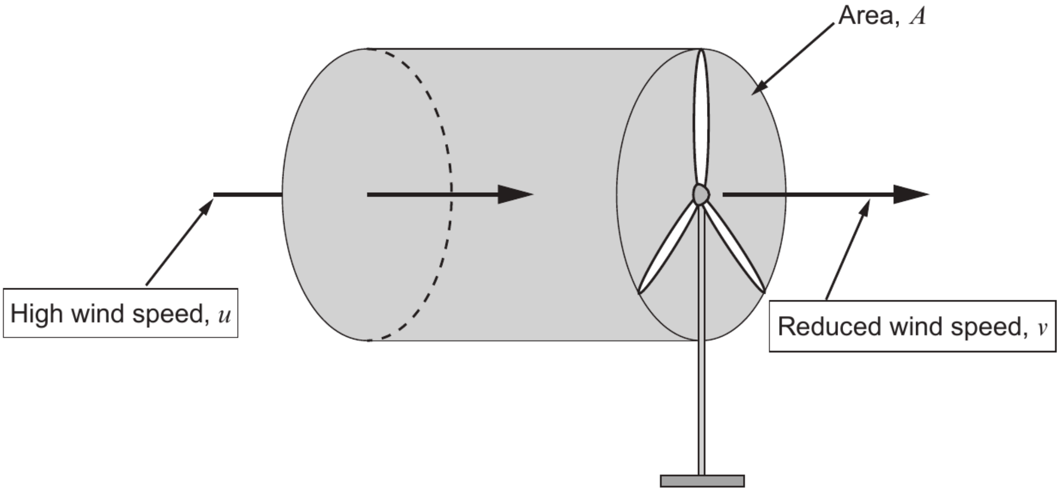
7. Wind turbines are used to generate electrical energy. They work by converting as much as possible of the kinetic energy of the air that moves through the area swept out by the blades into electrical energy.



(a) (i) The volume of air arriving on the blades per second is Au. Show that the kinetic energy per second (the power, P) arriving is given by:

$$P = \tfrac{1}{2} A\rho u^3$$

where ρ is the density of the air. [2]

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(ii) Use the above equation to complete the following sentences: [2]

(I) The power arriving is proportional to the *square of the radius.* So doubling the length of the turbine blades will increase the power arriving by a factor of

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(II) Doubling the wind speed will increase the power arriving by a factor of

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(iii) The blades cannot remove all the energy arriving from the wind. Having passed through the blades, the moving air has a reduced speed, v, as shown in the diagram. The following equation can be used to approximate the power possessed by this moving air:

$$P = \frac{1}{2} A \rho v^3$$

Use this equation and the one in *(a)*(i) to write an expression for the power **lost** by the air as it passes through the moving blades. [1]

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(iv) Suggest why it is not a good idea to erect wind turbines short distances behind each other. [1]

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(v) A wind turbine has blades of length 2.0 m. Wind of speed 7.0 m s^{-1} arrives on the blades, which is reduced to 5.0 m s^{-1} after passing through the blades. Calculate the net power input to the wind turbine. [Assume ρ_{air} = 1.2 kg m^{-3}.] [2]

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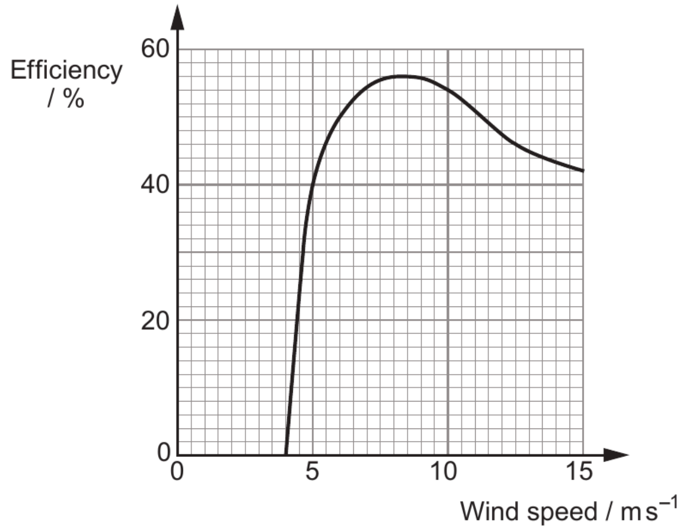
(b) The calculation in *(a)*(v) assumes that all the kinetic energy lost from the wind is converted into electrical energy. This is not the case as electrical generators in the wind turbines are not 100% efficient. A significant amount of energy is lost due to friction between the moving parts of the turbine for example. Below is a typical graph of efficiency against the speed of the wind arriving on the blades.



(i) Suggest why no power is generated for wind speeds up to $4.0\,\mathrm{m\,s^{-1}}$. [1]

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(ii) Use the graph to determine the actual power generated by the turbine in *(a)*(v) in a wind of speed $7.0\,\mathrm{m\,s^{-1}}$. [2]

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(c) State why an undersea turbine of the same size as the wind turbine in *(a)*(v), when placed in a water current of speed $7.0\,\mathrm{m\,s^{-1}}$, would provide significantly greater power output than the wind turbine. [1]

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END OF PAPER

END OF QUESTION PACK

3 questions · 31 marks · ~43 min

Source: WJEC PH1 (2008 modular spec)

Curated for WJEC Physics 2015 spec AS Unit 1 — Topic 4b (1.4)