Name	Date started	Target end date

GCE AS/A LEVEL – ENERGY QUESTION PACK

1321-01 (Legacy PH1)

PHYSICS – PH1

PH1.3 Energy Concepts – Comprehensive question pack

Every energy-themed question from the legacy WJEC PH1 papers (Jan 2009 – June 2015)

LEGACY 2008 SPECIFICATION

Estimated time for entire question pack: ~2 hours 30 minutes

*Derived from the legacy PH1 paper's pace of **~1 min/mark** (80 marks in 1¼ hours).*

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

For Examiner's use only

Q	Source	Max	Mark
1	Jun 10 Q7	16	
2	Jun 14 Q1	9	
3	Jun 13 Q5	12	
4	Jun 15 Q5	11	
5	Jun 09 Q8	11	
6	Jan 09 Q5	9	
7	Jan 12 Q4	11	
8	Jan 13 Q3	12	
9	Jan 11 Q7	10	
10	Jun 12 Q4	12	
11	Jan 09 Q7	7	
12	Jan 11 Q5	8	
13	Jan 14 Q7	16	
Total		144	

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every energy-themed question from the legacy WJEC PH1 papers between January 2009 and June 2015.

Questions are grouped by sub-topic within PH1.3 Energy Concepts, then ordered roughly by difficulty.

INSTRUCTIONS

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

A calculator is required. The Data Booklet is allowed.

PH1.3 Energy Concepts — what the legacy spec asks

WJEC GCE AS/A Level Physics (from 2008) · PH1 Assessment Unit *Motion, Energy & Charge* · PH1.3 *Energy Concepts*. Identical physics to the 2015 Topic 4.

Work & energy A

- Define work done as the product of force and displacement in the direction of the force.
- Understand the concept of energy as the capacity for doing work.
- SI unit of work and energy: the joule.

Power A

- Define power as the rate of doing work, or equivalently the rate of energy transfer: $P = W/t$.
- Apply $P = Fv$ for a body moving with constant velocity.
- SI unit: the watt.

Kinetic & potential energy B

- Derive and use $E_k = \frac{1}{2}mv^2$ for kinetic energy.
- Derive and use $\Delta E_p = mg\Delta h$ for changes in gravitational potential energy near the Earth's surface.
- Elastic strain energy stored in a spring: $E = \frac{1}{2}kx^2$ (or area under force-extension graph).

Conservation of energy B

- State the principle of conservation of energy.
- Apply it to convert between forms of energy — e.g. GPE → KE → heat (work against friction).

Efficiency C

- Efficiency = (useful energy output) / (total energy input).
- Often expressed as a percentage; always < 100% in real systems due to dissipation.

Working scientifically

- Read off areas under force-displacement and force-extension graphs to find work or stored energy.
- Compare expected (theoretical) and measured outputs to determine efficiency.

Section index for this question pack

A	**Work, energy & power principles**	Defining work and power, then applying conservation of energy to bodies on slopes, slides, bobsleighs, zip-wires and bungee jumps.	*59 marks · pp 4–14*
B	**Stored & released energy**	Gravitational and elastic PE transferred to KE — falling balls, hydroelectric reservoirs, spring-launched toys, longbows and bungee dynamics.	*54 marks · pp 15–26*
C	**Power generation & efficiency**	Power available from a moving fluid ($P = \frac{1}{2}\rho A v^3$), applied to tidal and wind turbines, plus generator efficiency.	*31 marks · pp 27–34*

Energy in one page

Quick-reference notes — revisit before each section.

Work done

$$W = F\,s\cos\theta$$

- F = applied force, s = displacement, θ = angle between them.
- No work done when $F \perp s$ (e.g. centripetal force on circular path).
- Unit: joule (J) = $\mathrm{N\,m} = \mathrm{kg\,m^2 s^{-2}}$.

Kinetic energy

$$E_k = \tfrac{1}{2}mv^2$$

- Scalar — always positive.
- Doubling v quadruples E_k.
- From work-energy theorem: net work = ΔE_k.

Gravitational PE

$$\Delta E_p = mg\,\Delta h$$

- Valid near Earth's surface ($g \approx 9.81\ \mathrm{m\,s^{-2}}$).
- Take a reference level — differences are what matter.
- For free fall: $\Delta E_p \to E_k$, so $v = \sqrt{2g\Delta h}$.

Elastic PE (springs)

$$E = \tfrac{1}{2}kx^2 = \tfrac{1}{2}Fx$$

- Area under a force–extension graph = stored energy.
- Only valid while the spring obeys Hooke's law: $F = kx$.
- k = stiffness / spring constant (N m $^{-1}$).

Conservation of energy

Total energy of an isolated system is conserved — energy can change form but not be created or destroyed.

Example: GPE lost = KE gained + work done against friction.

Lost KE is rarely "gone" — usually heat, sound, or deformation.

Power

$$P = W/t = \Delta E/\Delta t$$

For motion at velocity v against a force F:

$$P = Fv$$

- Unit: watt (W) = $\mathrm{J\,s^{-1}} = \mathrm{kg\,m^2 s^{-3}}$.
- Mechanical power at constant v = driving force × speed.

Efficiency

$$\eta = \frac{E_{\text{useful}}}{E_{\text{input}}} \times 100\%$$

Equivalent in power terms:

$$\eta = \frac{P_{\text{useful}}}{P_{\text{input}}}$$

- $\eta < 100\%$ — dissipative losses (heat, sound, deformation).

Power from a moving fluid

Volume per second through cross-section A at speed v: Av.

Mass per second: ρAv.

Kinetic energy per second:

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

Used for wind turbines, tidal turbines, hydroelectric flow.

Free fall energy

Ignoring air resistance, $mgh = \tfrac{1}{2}mv^2$:

$$v = \sqrt{2gh}$$

- If air resistance acts: some GPE → heat.
- Compare measured v to $\sqrt{2gh}$ to estimate energy lost.

Work against friction

$$W_{\text{friction}} = F_{\text{f}}\,d$$

Energy balance on a slope/slide:

$$mgh = \tfrac{1}{2}mv^2 + W_{\text{friction}}$$

So $F_{\text{f}} = (mgh - \tfrac{1}{2}mv^2)/d$.

Bungee / spring energy

At lowest point of bungee jump: jumper momentarily stationary $\Rightarrow$ all GPE has transferred to elastic PE in the cord.

$$mgh_{\text{drop}} = \tfrac{1}{2}k\,x_{\text{ext}}^2$$

- Use this to find spring constant k.
- At rest position: $kx = mg \Rightarrow x = mg/k$.

Resistive forces (vehicles)

At terminal/constant velocity: driving force = resistive force.

- $P_{\text{driving}} = F_{\text{driving}}\,v = F_{\text{resistive}}\,v$ when $a = 0$.
- Resistive force often grows with speed (air drag).

SECTION A

Work, energy & power principles

Questions 1 – 5 · 59 marks

7. *(a)* (i) Define *work.* [2]

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(ii) Hence express the unit of work, J, in terms of the SI base units kg, m and s. [2]

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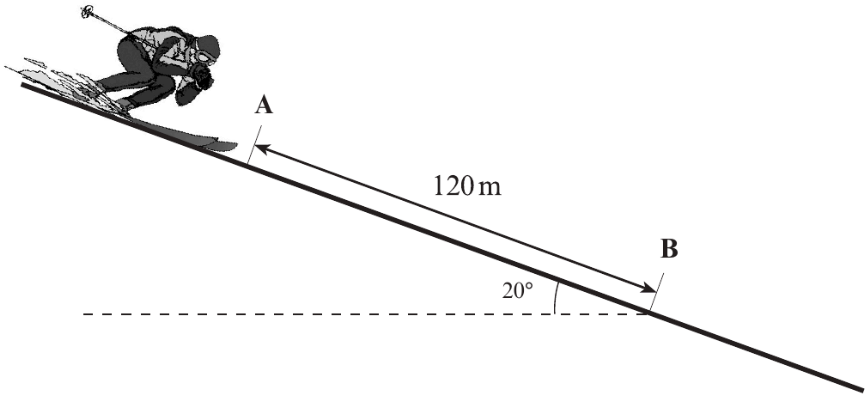
(b)



A skier of mass 70 kg descends a slope inclined at 20° to the horizontal as shown. The skier passes point **A** at a speed of 6 ms^{-1} and a second point **B** at a speed of 21 ms^{-1}. The distance between **A** and **B** is 120 m. Calculate, for the descent from **A** to **B**,

(i) the gravitational potential energy lost by the skier; [2]

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(ii) the kinetic energy gained by the skier. [3]

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(c) (i) State the principle of conservation of energy. [1]

(ii) Discuss your answers to *(b)* (i) and (ii) in terms of this principle. [2]

(d) Calculate the mean resistive force experienced by the skier between **A** and **B**. [4]

QUESTION 8 IS ON PAGE 14

Examiner only

Answer **all** *questions.*

1. *(a)* (i) State the principle of conservation of energy. [1]

(ii) Explain how the principle applies to an object falling from rest **through the air**. [3]

(b) A child of mass 16 kg starts from rest at the top of a playground slide and reaches the bottom of the slide with a speed of 6.0 m s^{-1}. The slide is 4.0 m long and there is a difference in height of 2.4 m between the top and the bottom.

(i) Calculate the work done against friction. [3]

(ii) Use your answer to *(b)*(i) to calculate the mean frictional force acting on the child. [2]

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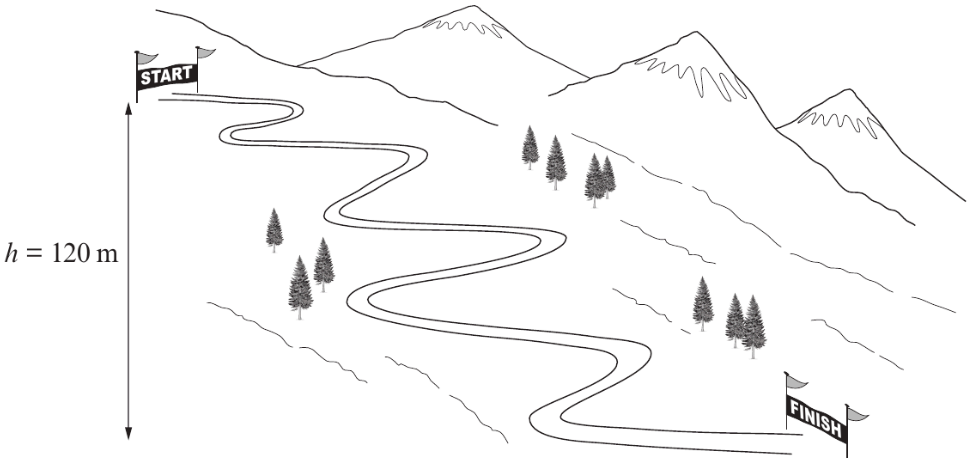
5. *(a)* State the principle of conservation of energy. [1]

(b) A bobsleigh run in Norway has a curving track of overall length 1.4 km from start to finish. During a run, the bobsleigh starts from rest, and drops through a vertical height, *h*, of 120 m.



(i) Assuming no resistive forces, show that the maximum possible speed, *v*, of a bobsleigh at the finish line is given by [2]

$$v = \sqrt{2gh}$$

(ii) Hence calculate the maximum possible speed of a bobsleigh at the finishing line. [1]

(c) (i) Due to resistive forces, the actual speed at the finishing line is **20% less** than the maximum possible speed. Give **two** examples of resistive forces acting on the bobsleigh. [2]

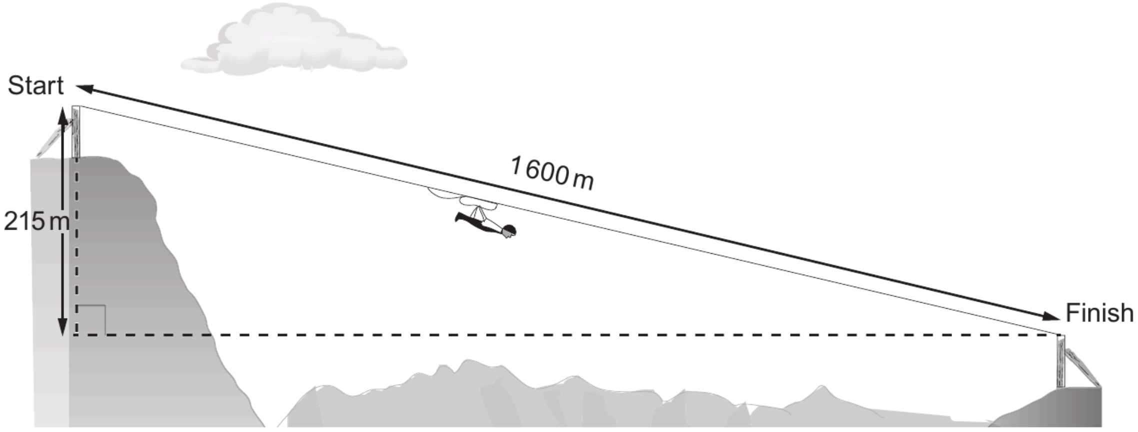
(ii) Taking the resistive forces into account, calculate the kinetic energy of the bobsleigh at the finish. The mass of the bobsleigh and riders = 280 kg. [2]

(iii) Hence, determine the mean resistive force experienced by the bobsleigh from start to finish. [4]

5. *(a)* (i) Define *power.* [1]

(ii) Show how the unit **W** can be expressed in terms of the SI base units **kg**, **m** and **s**. [2]

(b) The longest zip-wire ride in the UK is in Snowdonia, North Wales. It is 1600 m long and the vertical drop from start to finish is 215 m as shown. The diagram is not to scale.



(i) A person of mass 70 kg arrives at the finish travelling at 35 m s^{-1}, having started from rest. Use this data and information from the diagram opposite to determine the mean force opposing the motion of the person. [4]

(ii) The time taken to travel from start to finish is 46 s. Calculate the mean rate at which energy is transferred to the surroundings during the journey. [2]

8. (a) State the principle of conservation of energy.

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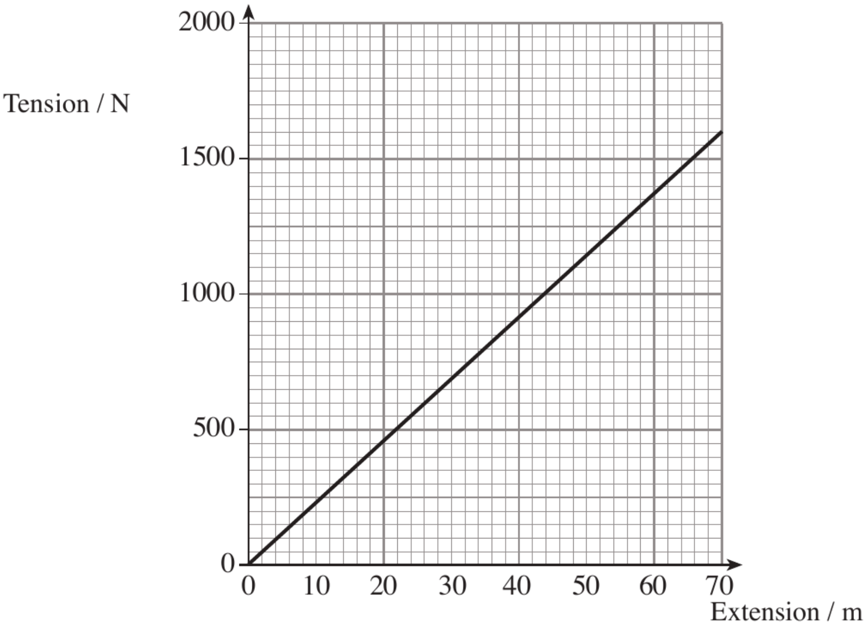
[2]

(b) A 'bungee jumper' standing on a high platform above the ground is attached to a bungee cord of unstretched length 26 m and spring constant k. When she jumps she falls a maximum distance of 96 m where she is momentarily stationary at the lowest point of her jump and about to begin moving upwards. Ignore air resistance.



(i) The graph shows how the tension in the bungee cord varies with extension during the fall. Use the graph to calculate the elastic potential energy stored in the bungee cord when the jumper is at the lowest point.

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[3]

(ii) The initial gravitational potential energy (with respect to the ground) possessed by the jumper on the platform is 7.0×10^4 J and her mass is 60 kg. Calculate how high she is above the ground at the bottom of her fall.

[3]

(iii) After 'bouncing' a few times, the bungee jumper eventually comes to rest hanging a distance, d, below the platform. Calculate the value of d.

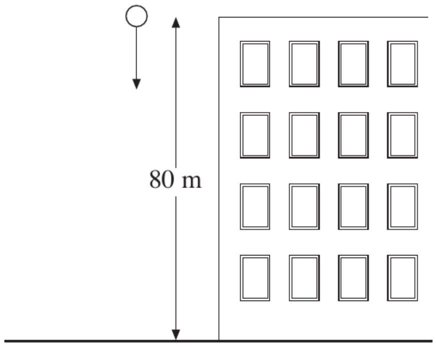
[3]

SECTION B

Stored & released energy

Questions 6 – 10 · 54 marks

5. A ball of mass 0·60 kg is dropped from the top of a building 80 m high.



(a) Calculate the initial gravitational potential energy of the ball. [2]

(b) The ball reaches the ground with a velocity of 30 $\mathrm{m\,s^{-1}}$. Calculate its kinetic energy. [2]

(c) (i) Calculate the fraction of the initial gravitational potential energy that is not converted into kinetic energy of the ball during the fall. [1]

(ii) Explain, referring to molecules, what has happened to this ‘missing’ energy. [2]

(d) Calculate the mean resistive force acting on the ball during its fall. [2]

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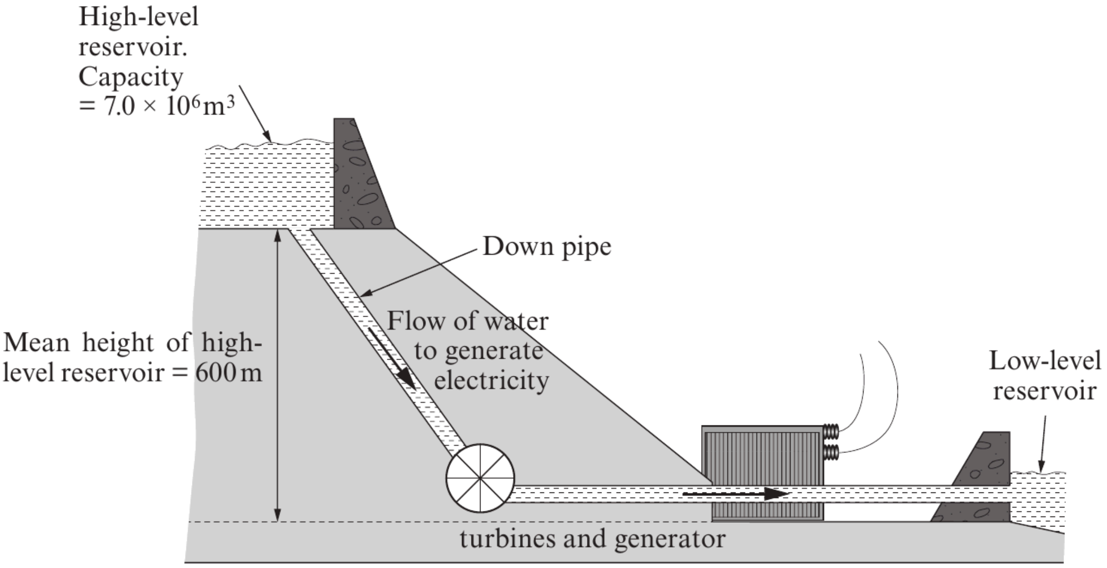
4. The hydroelectric power station at Dinorwig in North Wales is the largest of its kind in Europe. A simplified diagram showing the main features of the plant is shown.



(a) Use the information in the diagram to show that the gravitational potential energy stored in the high-level reservoir is approximately 4×10^{13} J.
[Density of water = 1000 kg m^{-3}]. [2]

(b) The power plant has six 300 MW generators. Calculate the longest time for which the stored energy could provide power at maximum output given that the generation process is 90% efficient [i.e. 10% of the gravitational potential energy stored in the high level reservoir is wasted]. [3]

(c) (i) Calculate the mean rate of flow of water (in kg s^{-1}) through the turbines of the power station when it is operating at full power. [1]

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(ii) After passing through the turbines the water enters the lower lake at a speed of $20\,m\,s^{-1}$. Use your answer to *(c)*(i) to calculate the kinetic energy per second [power] of this water. [1]

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(iii) Calculate the **wasted energy per second** (power lost) during the generation process. [2]

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(iv) Hence show that your answer to *(c)*(ii) represents between 30% and 40% of the wasted power. [1]

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(v) Where else would energy be wasted during the generating process? [1]

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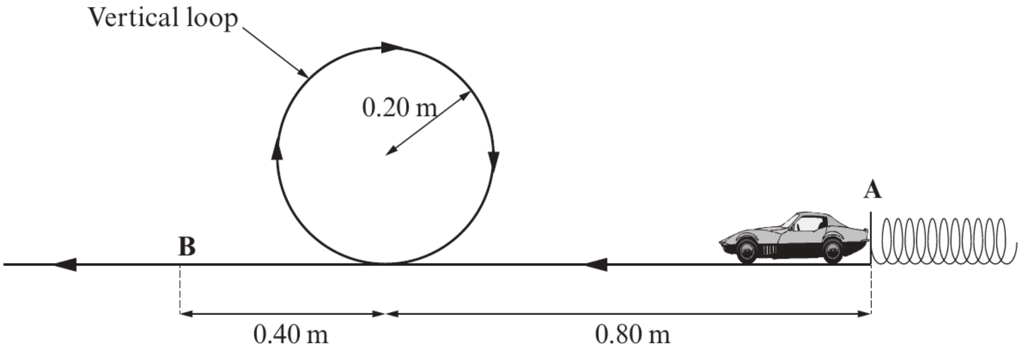
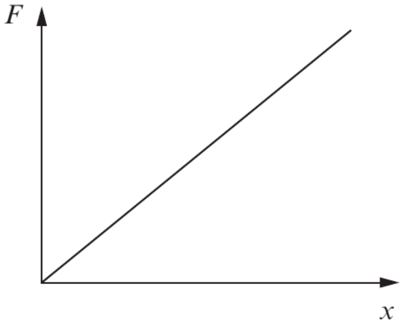
3. A compressed spring is used to shoot a small toy car along a track which contains a circular vertical loop of radius 0.20 m. The spring obeys Hooke's law. Points **A** and **B** are referred to later in the question.



(a) The sketch graph shows how the extension, x, of the spring varies with the force, F, applied to it.



(i) Explain how the graph shows that the spring obeys Hooke's law. [1]

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(ii) Use the graph to show that the elastic potential energy stored in the spring $= \frac{1}{2}kx^2$, where k is the spring constant. [2]

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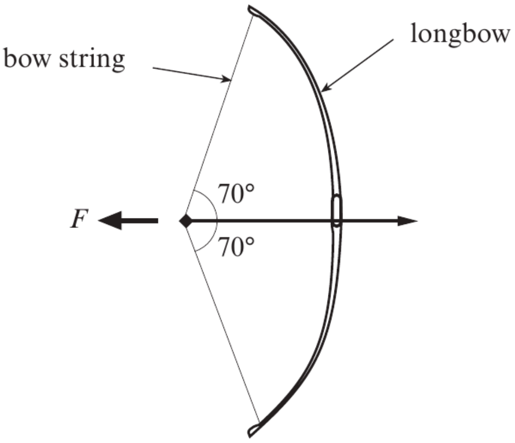
(b) The spring requires a force of 0.10 N to compress it 1.0 mm.

(i) Calculate the elastic potential energy stored in it when it is compressed by 80 mm. [3]

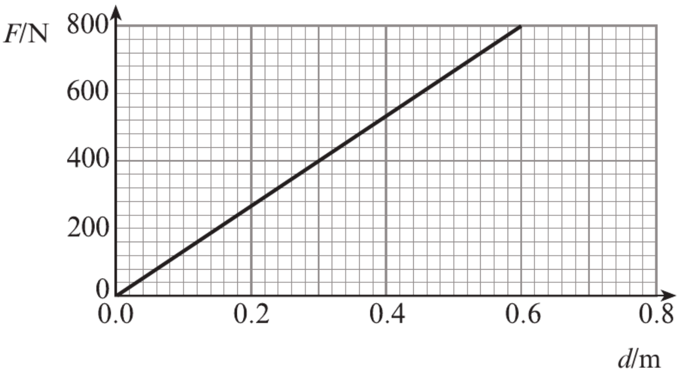
(ii) A small car of mass 0.04 kg is placed at point **A**, against the end of the spring, which is then released. Using your answer to *(b)*(i), calculate the speed with which the car leaves the spring. [2]

(c) The speed of the car at point **B** (after it has completed the loop) is **0.2 m s^{-1} less than its speed at A**. Determine the mean frictional force on the car during its motion from **A** to **B**. [4]

7. *(a)* The medieval longbow was a devastatingly effective weapon. Assuming that a horizontal force F of 800 N is needed to draw back the bow string, show that the tension T in the string is approximately 1170 N. [2]

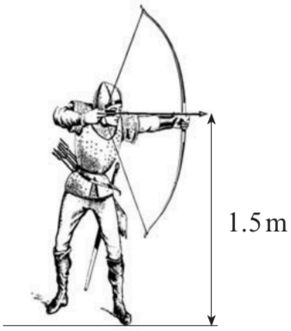


(b) (i) The graph shows the variation of F with d for the longbow, where d is the distance the centre of the string is pulled back. Calculate the energy stored in the bow when the tension in the string is 1170 N. [2]



(ii) Hence, **stating any assumptions you make**, show that the speed of the arrow as it leaves the bow is about 100 m s^{-1}. Take the mass of the arrow to be 50×10^{-3} kg. [3]

(c) The arrow is released horizontally at this speed from 1.5 m above the ground as shown. The arrow continues its path until it embeds itself into the ground a horizontal distance *D* from the point of release. **Ignoring the effects of air on the arrow**, calculate



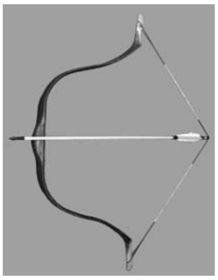
(i) the time taken for the arrow to reach the ground, [3]

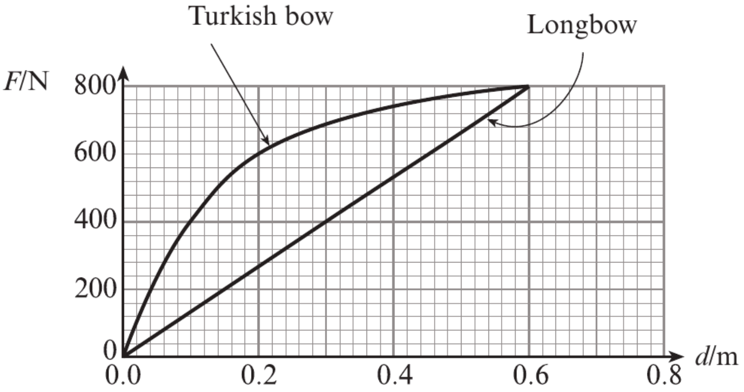
(ii) the horizontal distance *D*, [2]

(iii) the **resultant velocity** of the arrow when it hits the ground. [5]

QUESTION 7 CONTINUES ON PAGE 16

(d) The Turkish war-bow of the 15th and 16th centuries (pictured) was also a fearsome weapon, able to shoot lightweight arrows great distances. A copy of the graph on page 14 is shown below which has included on it a curve to represent the draw force versus ‘pull back distance’ for a typical Turkish bow.

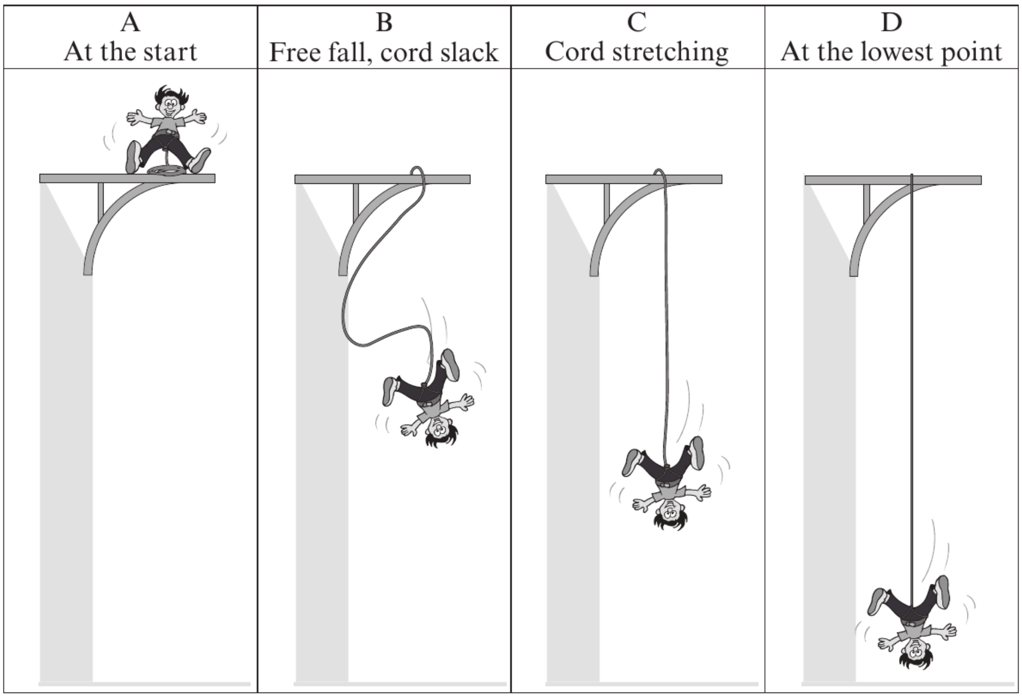




Use the graphs to compare the effectiveness of the Turkish bow in relation to the longbow. Your answer could refer to the ease of use of each bow, the energy stored and the effect this has on motion of an arrow.

Calculations are not required. [4]

4. *(a)* By referring to the diagrams, discuss some of the energy changes involved in a bungee jump. You should make reference to *gravitational potential energy*, *kinetic energy* and *elastic potential energy* in your answer. [5]



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(b) A bungee jumper of mass 70 kg jumps from a high bridge using a bungee cord of natural length 80 m. When he reaches the lowest point for the first time the length of the cord is 130 m. Calculate

(i) the loss of gravitational potential energy from his position on the bridge to the lowest point for the first time, [2]

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(ii) the stiffness constant *(k)* of the bungee cord assuming the cord obeys Hooke's law and that there are no losses due to air resistance, [3]

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(iii) the extension of the cord when he finally comes to rest (after having 'bounced' a few times). [2]

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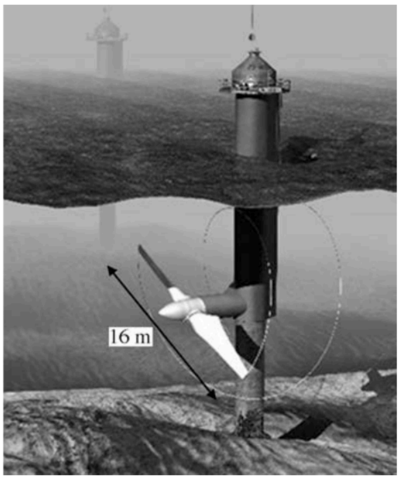
SECTION C

Power generation & efficiency

Questions 11 – 13 · 31 marks

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]

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

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

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]

(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]

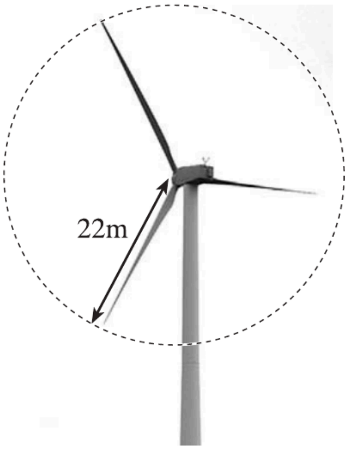
(iii) Explain in terms of the kinetic energy of the water why the turbine is not 100% efficient. [1]

(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]

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

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 $\mathrm{m^3\,s^{-1}}$, when the wind speed is $14\,\mathrm{m\,s^{-1}}$. [2]

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

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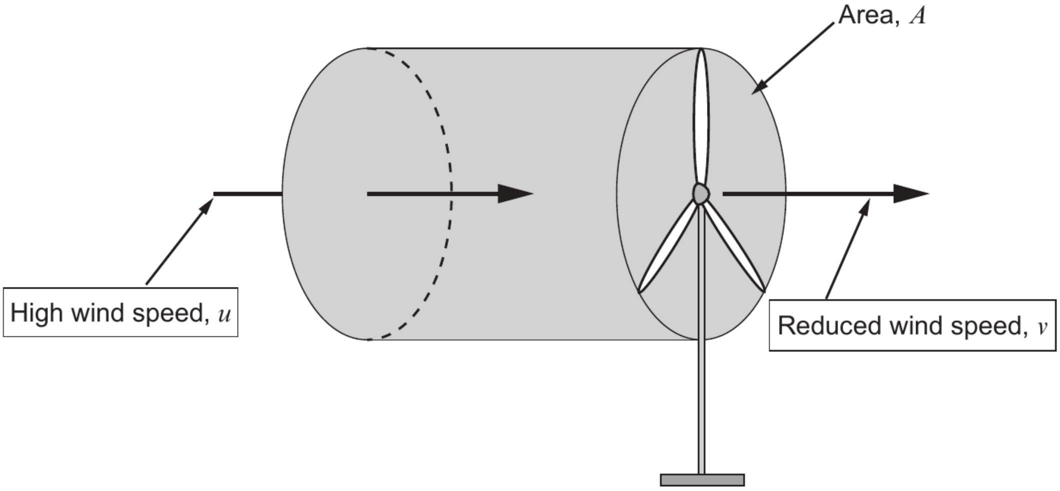
7. Wind turbines are used to generate electrical energy. They work by converting as much as possible of the kinetic energy of the air that moves through the area swept out by the blades into electrical energy.



(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

....

(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:

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

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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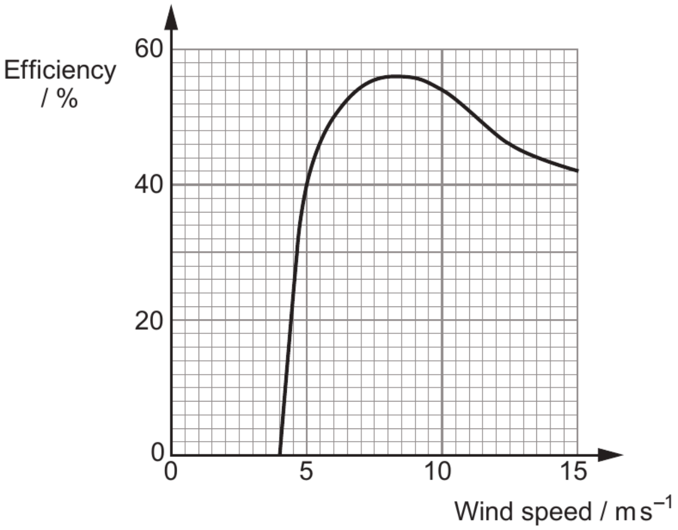
(b) The calculation in *(a)*(v) assumes that all the kinetic energy lost from the wind is converted into electrical energy. This is not the case as electrical generators in the wind turbines are not 100% efficient. A significant amount of energy is lost due to friction between the moving parts of the 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 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 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 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