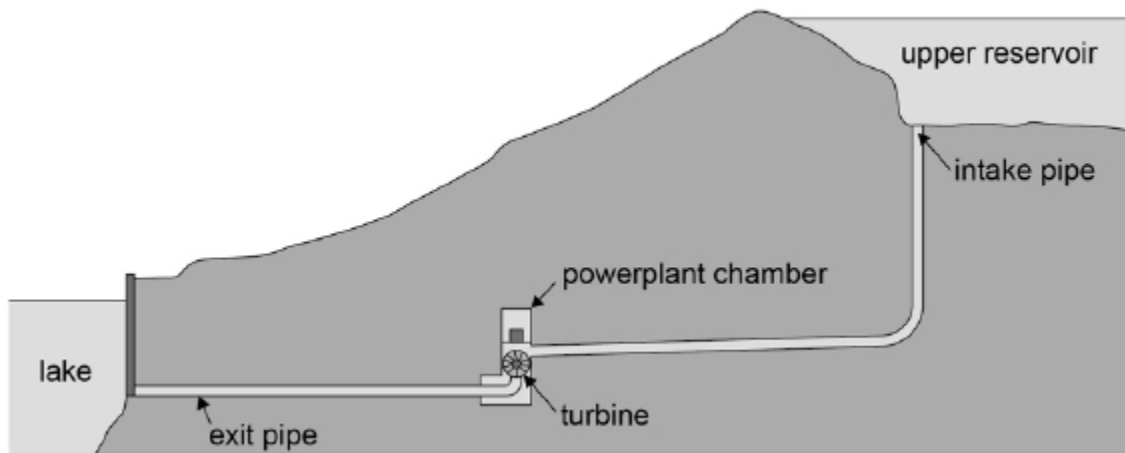


**1**

The diagram below shows a possible design for a pumped storage system used to generate electricity.



Water from the upper reservoir is to fall through a vertical distance of 90 m before reaching a powerplant chamber. The water rotates a turbine in the chamber that drives an electricity generator. After leaving the turbine, the water travels through an exit pipe to a lake.

- (a) Show that the maximum possible speed of the water as it arrives at the turbine is about  $40 \text{ m s}^{-1}$ .

(2)

- (b) The volume of water flowing into the turbine every second is  $3.5 \text{ m}^3$ .

Estimate the radius of the intake pipe that is required for the system.

pipe radius = \_\_\_\_\_ m

(2)

- (c) The water leaves the powerplant chamber at a speed of  $12 \text{ m s}^{-1}$ .

Calculate the maximum possible power output of the turbine and generator.  
Give an appropriate unit for your answer.

density of water =  $1000 \text{ kg m}^{-3}$

Maximum power output = \_\_\_\_\_ unit = \_\_\_\_\_

(4)

- (d) Energy losses are estimated to reduce the output power for the turbine and generator to 60% of the value you calculated in part (c).

Explain **two** possible reasons for this energy loss.

1. \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

2. \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(2)

(Total 10 marks)

2

A roller coaster car is raised to a height of 65 m and released from rest.

What is the maximum possible speed of the car?

A  $11 \text{ m s}^{-1}$

☐

B  $25 \text{ m s}^{-1}$

☐

C  $36 \text{ m s}^{-1}$

☐

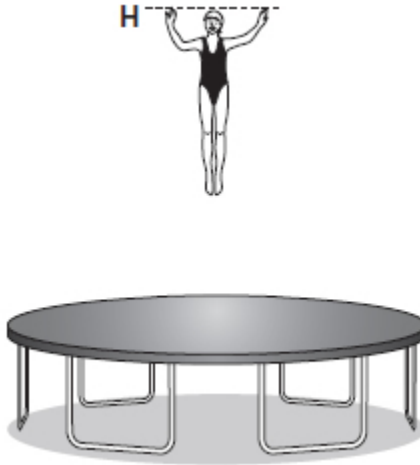
D  $130 \text{ m s}^{-1}$

☐

(Total 1 mark)

3

The diagram shows a girl bouncing vertically on a trampoline. The highest point that she reaches is **H**.



Describe the energy changes involved as the girl bounces from position **H** and back to the same position shown in the diagram.

You should consider the energy losses that occur during this motion.

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(Total 3 marks)

4

(a) State the law of conservation of energy.

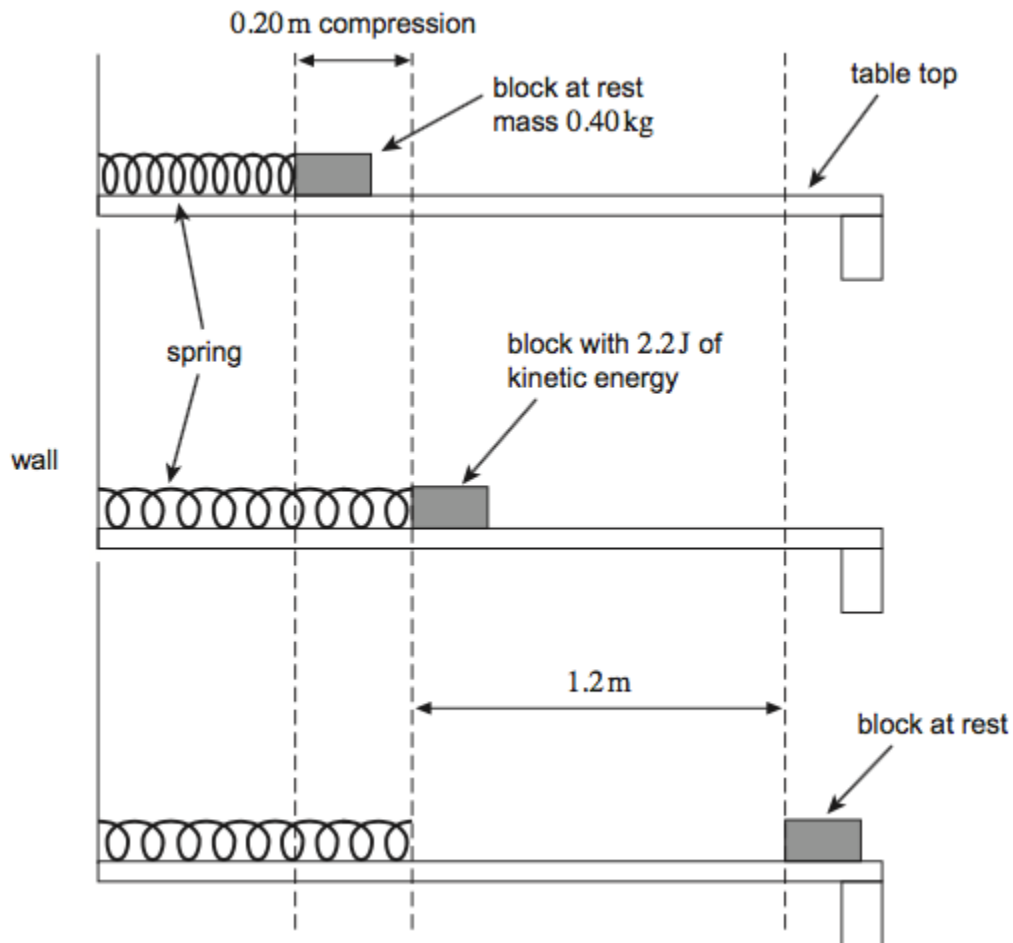
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(2)

- (b) The diagram shows a block on a horizontal table top initially held against a spring so that the spring is compressed. The other end of the spring is fixed to a wall. When released the block is pushed away by the spring. When the spring reaches its natural length the block leaves the spring and then slides along the table top. A constant frictional force acting between the moving block and the table top eventually brings the block to rest.



- (i) When the block leaves the spring, the block has a kinetic energy of 2.2 J. The mass of the block is 0.40 kg.  
Calculate the maximum velocity of the block.

maximum velocity = \_\_\_\_\_  $\text{m s}^{-1}$

(1)

- (ii) The block travels 1.2 m after leaving the spring before coming to rest.  
Show that the frictional force between the block and the table top is about 1.8 N.

(1)

- (iii) The spring was initially compressed through 0.20 m. The constant frictional force acts on the block whenever it is moving.  
Calculate the elastic potential energy in the spring when in its initial compressed position.  
Assume the spring has negligible mass.  
State an appropriate unit for your answer.

elastic potential energy = \_\_\_\_\_ unit = \_\_\_\_\_

(3)

- (iv) The force exerted on the block by the spring is proportional to the compression of the spring.  
Calculate the maximum force exerted on the block by the spring.

maximum force = \_\_\_\_\_ N

(1)

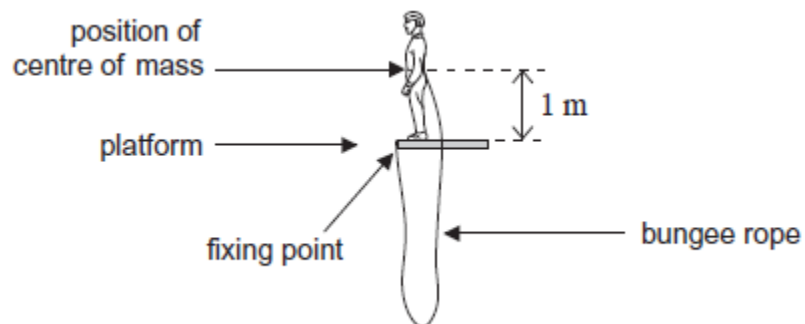
(Total 8 marks)

5

The diagram below shows a bungee jumper of mass 75 kg about to step off a raised platform. The jumper comes to a halt for the first time when his centre of mass has fallen through a distance of 31 m.

The bungee rope has an unextended length of 19 m and a stiffness of  $380 \text{ N m}^{-1}$ .

Ignore the effects of air resistance and the mass of the rope in this question.  
Treat the jumper as a point mass located at the centre of mass.



- (a) (i) Calculate the extension of the bungee rope when the centre of mass of the jumper has fallen through 31 m.

extension \_\_\_\_\_ m

**(1)**

- (ii) Calculate the resultant force acting on the jumper when he reaches the lowest point in the jump.

resultant force \_\_\_\_\_ N

**(2)**

- (b) Calculate the extension of the rope when the jumper's acceleration is zero.

extension \_\_\_\_\_ m

**(2)**

- (c) The extension of the bungee rope is 5.0 m when the jumper's centre of mass has fallen through a distance of 25 m.

Use the principle of conservation of energy to calculate the speed of the jumper in this position.

speed \_\_\_\_\_ m s<sup>-1</sup>

**(4)**

- (d) The bungee jump operator intends to use a bungee rope of the same unextended length but with a much greater stiffness. The rope is to be attached in the same way as before.

Explain, with reference to the kinetic energy of the jumper, any safety concerns that may arise as the jumper is slowed down by the new rope.

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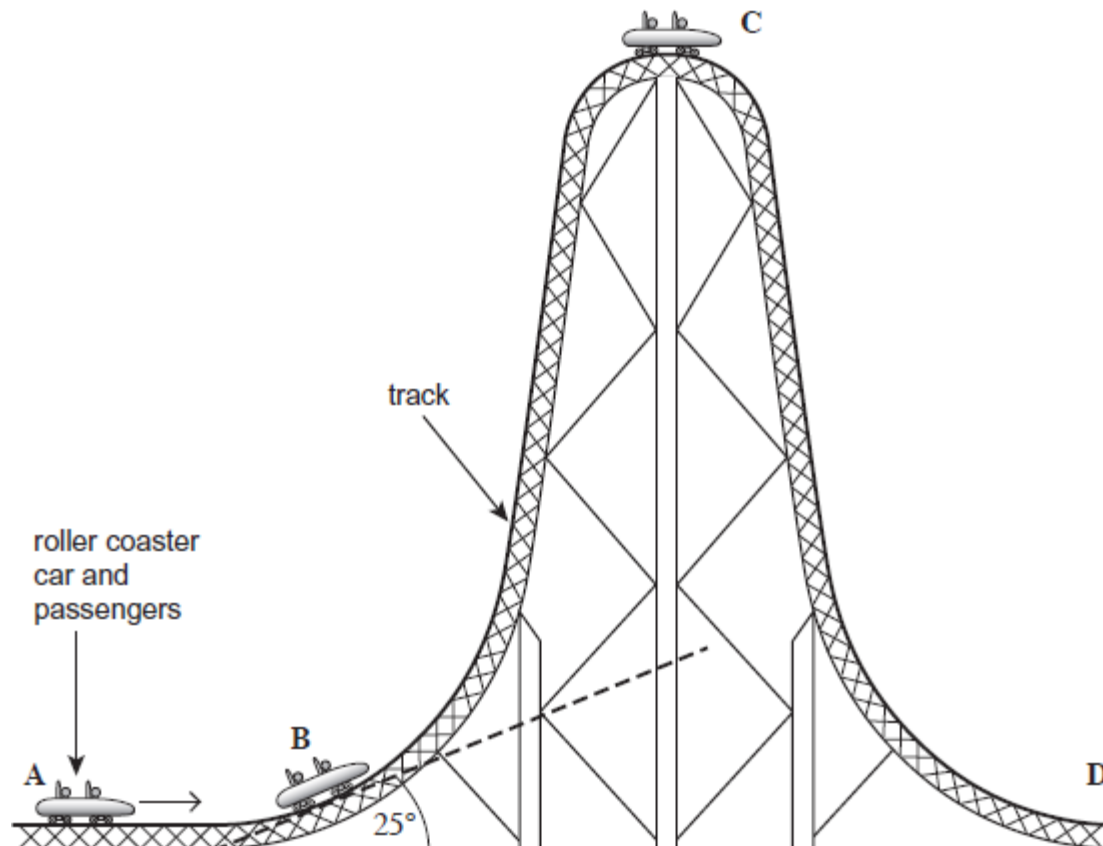
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**(3)**

**(Total 12 marks)**

**6**

The following figure shows a roller coaster car which is accelerated from rest to a speed of  $56 \text{ m s}^{-1}$  on a horizontal track, **A**, before ascending the steep part of the track. The roller coaster car then becomes stationary at **C**, the highest point of the track. The total mass of the car and passengers is  $8300 \text{ kg}$ .



- (a) The angle of the track at **B** is  $25^\circ$  to the horizontal. Calculate the component of the weight of the car and passengers acting along the slope when the car and passengers are in position **B** as shown in the image above.

component of weight \_\_\_\_\_ N

(2)

- (b) (i) Calculate the kinetic energy of the car including the passengers when travelling at  $56 \text{ m s}^{-1}$ .

kinetic energy \_\_\_\_\_ J

(2)

- (ii) Calculate the maximum height above **A** that would be reached by the car and passengers if all the kinetic energy could be transferred to gravitational potential energy.

maximum height \_\_\_\_\_ m

(2)

- (c) The car does not reach the height calculated in part (b).

- (i) Explain the main reason why the car does not reach this height.

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(2)

- (ii) The car reaches point **C** which is at a height of 140 m above **A**. Calculate the speed that the car would reach when it descends from rest at **C** to its original height from the ground at **D** if 87% of its energy at **C** is converted to kinetic energy.

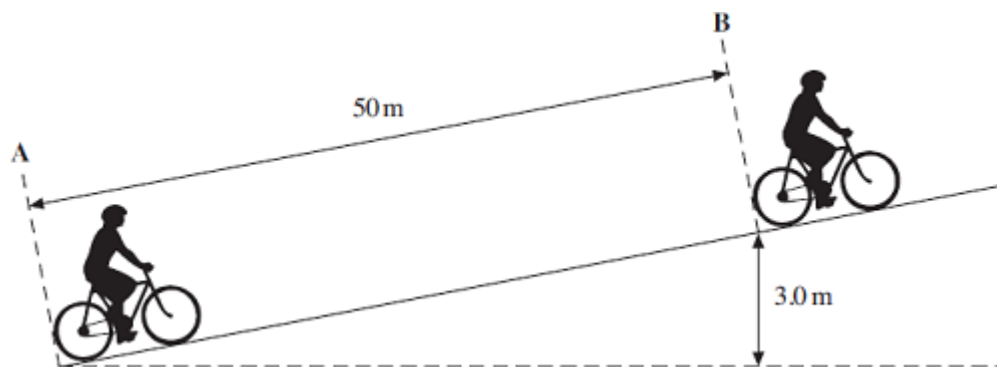
speed \_\_\_\_\_ m s<sup>-1</sup>

(2)

(Total 10 marks)

7

An 'E-bike' is a bicycle that is assisted by an electric motor. The figure below shows an E-bike and rider with a total mass of 83 kg moving up an incline.



- (a) (i) The cyclist begins at rest at **A** and accelerates uniformly to a speed of  $6.7 \text{ m s}^{-1}$  at **B**. The distance between **A** and **B** is 50 m. Calculate the time taken for the cyclist to travel this distance.

\_\_\_\_\_ s

(2)

- (ii) Calculate the kinetic energy of the E-bike and rider when at **B**. Give your answer to an appropriate number of significant figures.

\_\_\_\_\_ J

(2)

- (iii) Calculate the gravitational potential energy gained by the E-bike and rider between **A** and **B**.

\_\_\_\_\_ J

(2)

- (b) Between **A** and **B**, the work done by the electric motor is 3700 J, and the work done by the cyclist pedalling is 5300 J.

- (i) Calculate the wasted energy as the cyclist travels from **A** to **B**.

\_\_\_\_\_ J

(2)

- (ii) State **two** causes of this wasted energy.

Cause 1 \_\_\_\_\_

\_\_\_\_\_

Cause 2 \_\_\_\_\_

\_\_\_\_\_

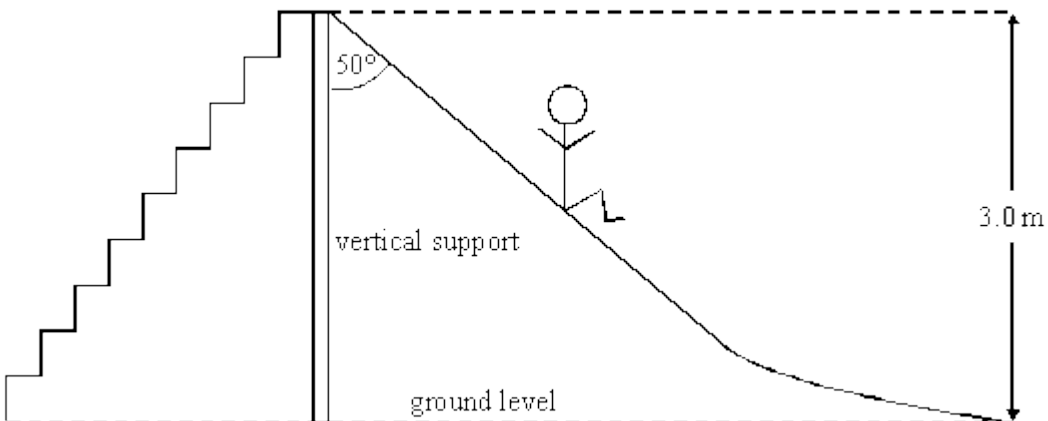
(2)

(Total 10 marks)

8

The diagram below shows a child coming down a slide in a playground. The vertical height of the slide is 3.0 m. The angle between the main slope of the slide and its vertical support is  $50^\circ$ .

acceleration of free fall  $g = 9.8 \text{ m s}^{-2}$



- (a) The child has a mass of 41 kg. Calculate the gain in gravitational potential energy as the child climbed to the top of the slide.

Gravitational potential energy gained \_\_\_\_\_

(2)

(b) Assume that the slide is frictionless.

- (i) Use your answer to part (a) to calculate the speed of the child when reaching the bottom of the slide.

Speed \_\_\_\_\_

(2)

- (ii) Calculate the resultant force acting on the child when in the position shown in the diagram above.

Resultant force \_\_\_\_\_

(2)

(Total 6 marks)

9

A bungee rope of unstretched length 50 m is designed to allow a 70 kg man to come to rest 85 m below the platform from which he jumps.

- (a) Calculate the energy stored in the rope when the man has come to rest.

Ignore the weight of the rope.

Gravitational field strength,  $g = 9.8 \text{ N kg}^{-1}$

Energy stored \_\_\_\_\_

(2)

- (b) Calculate the gravitational potential energy lost by the man when he has come to rest.

Gravitational potential energy \_\_\_\_\_

(3)

(Total 5 marks)

10

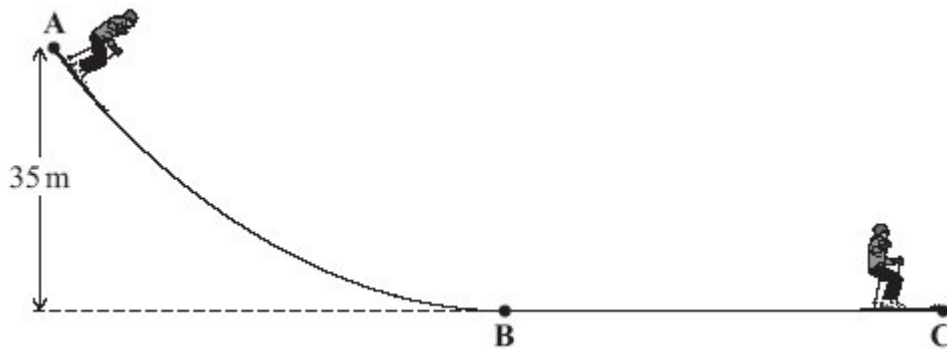
A stone is projected horizontally by a catapult consisting of two rubber cords. The cords, which obey Hooke's law, are stretched and released. When each cord is extended by  $x$ , the stone is projected with a speed  $v$ . Assuming that all the strain energy in the rubber is transferred to the stone, what is the speed of the stone when each cord is extended by  $2x$ ?

- A  $v$
- B  $\sqrt{2}v$
- C  $2v$
- D  $4v$

(Total 1 mark)

11

The diagram below shows the path of a skier who descends a slope **AB**.



The skier starts from rest at **A** and eventually comes to rest again at **C** on the horizontal surface **BC**.

- (a) (i) The slope **AB** has a vertical height of 35 m. The total mass of the skier is 65 kg.

Show that the skier's loss in gravitational potential energy is about 20 kJ.

(1)

- (ii) The kinetic energy of the skier at point **B** is 11 000 J.  
Show that the skier's speed at point **B** is about  $18 \text{ m s}^{-1}$ .

(2)

- (iii) The average retarding force acting on the skier is 140 N.  
Calculate the distance travelled between **A** and **B**.

distance travelled \_\_\_\_\_ m

(2)

- (iv) Describe **two** ways in which the retarding force may arise.

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(3)

(b) The skier decelerates uniformly between **B** and **C** at  $2.8 \text{ m s}^{-2}$ .

(i) Calculate the time taken to travel from **B** to **C**.

time \_\_\_\_\_ s

(2)

(ii) Calculate the distance **BC**.

distance \_\_\_\_\_ m

(2)

(Total 12 marks)

12

The table below indicates some positions of a person carrying out a bungee jump from a high bridge.

Tick the appropriate box(es) to show the forms that the jumper's energy takes at the different stages of the jump.

| Energy forms<br>Position                                       |                |                                |                          |
|----------------------------------------------------------------|----------------|--------------------------------|--------------------------|
|                                                                | kinetic energy | gravitational potential energy | elastic potential energy |
| at the instant the jumper steps off the bridge                 |                |                                |                          |
| at the instant the elastic bungee rope just becomes taut       |                |                                |                          |
| at the instant the jumper reaches the lowest point of the jump |                |                                |                          |

(Total 3 marks)

**13**

It has been predicted that in the future large offshore wind turbines may have a power output ten times that of the largest ones currently in use. These turbines could have a blade length of 100 m or more. A turbine such as this is shown in the diagram below.



- (a) At a wind speed of  $11 \text{ m s}^{-1}$  the volume of air passing through the blades each second is  $3.5 \times 10^5 \text{ m}^3$ .

- (i) Show that the mass of air that would pass through the blades each second is about  $4 \times 10^5 \text{ kg}$ .

The density of air is  $1.2 \text{ kg m}^{-3}$

(2)

- (ii) Calculate the kinetic energy of the air that would enter the turbine each second.

answer = \_\_\_\_\_ J

(2)

- (iii) It has been predicted that the turbine would produce an electrical power output of 10 MW in these wind conditions. Calculate the percentage efficiency of the turbine in converting this kinetic energy into electrical energy.

answer = \_\_\_\_\_ %

(2)

- (b) State **one** advantage and **one** disadvantage of wind power in comparison to fossil fuel.

Advantage \_\_\_\_\_

\_\_\_\_\_

Disadvantage \_\_\_\_\_

\_\_\_\_\_

(2)

(Total 8 marks)

## Mark schemes

1

(a)  $E_k E_p$  or  $v = \sqrt{2gh}$  ✓

$$= \sqrt{2 \times 9.81 \times 90}$$

$$= 42.0 \text{ (m s}^{-1}\text{)} \text{ ✓}$$

*First mark for realising energy transformation from GPE to KE.*

*Second mark for correct answer.*

2

(b) calculation of area of pipe (=0.0833 m<sup>2</sup>) ✓

$$\text{radius} = \sqrt{\frac{0.0833}{\pi}} = 0.16 \text{ (m)} \text{ ✓}$$

2

(c) mass of water / s = 3500 kg ✓

$$\text{energy available per second} = 0.5 \times 3500 \times (42^2 - 12^2) \text{ ✓}$$

$$= 2.8 \text{ ✓ MW ✓}$$

4

(d) heat / mechanical friction in turbines ✓

friction at walls of pipes / turbulence ✓

electrical heating in wires ✓

*Do **not** allow (friction) bald.*

*Seat of loss must be clear.*

Max 2

[10]

2

C

[1]

3

GPE to KE and / or elastic potential (and reverse)

Energy is lost due to work done on air / trampoline

Work done by child (on trampoline) makes up for energy losses

*No B1 mark for an incorrect energy change*

*Accept air resistance for an energy loss*

[3]

4

(a) energy cannot be created or destroyed ✓

it can only be transferred / changed / converted from one form to another ✓

*'Transformed' can be taken to mean transferred from one form to another.*

(b) (i) (using  $E_k = \frac{1}{2} mv^2$ )

$$2.2 = \frac{1}{2} \times 0.40 \times v^2$$

$$v = 3.3 \text{ (ms}^{-1}\text{)} \checkmark$$

*Ignore errors in 3 sig fig.*

*Answer only can gain mark.*

1

(ii) (using work done =  $F \times s$ )  $2.2 = F \times 1.2 \checkmark$  ( $F = 1.83 \text{ N}$ ) or

(using  $a = (v^2 - u^2) / 2s$ )

$$a = (0^2 - 3.32^2) / 2 \times 1.2 = (-) 4.59 \text{ (m s}^{-1}\text{)}$$

$$(F = ma) = 0.4 \times 4.59 \checkmark = (1.84 \text{ N})$$

*A substitution of numbers are necessary for the mark*

1

(iii) (work done in moving 0.2 m) =  $1.8 \times 0.2 \text{ (J)} \checkmark$  (= 0.36 J)

(allow ecf (bii)  $\times 0.2$ )

$$\text{total work done} = 2.2 + 0.36 = 2.6 \checkmark \text{ (same answer is achieved if } F = 2\text{N)}$$

J or joule  $\checkmark$

3

(iv) (use of energy =  $\frac{1}{2} Fx$ )

$$2.6 = \frac{1}{2} F_{\max} 0.2$$

$$F_{\max} = 26 \text{ N} \checkmark$$

(allow ecf  $10 \times$  (biii))

*Allow mark for answer only even for ecf.*

1

[8]

5

(a) (i) 11 (m)

B1

1

(ii) Use of  $F = k\Delta L$  or  $W = mg$

*Allow use of  $\Delta L = 12 \text{ m}$*

C1

$$3400 \text{ (N)}$$

A1

2

(b) Sets  $mg = k\Delta L$

C1

$$1.9 \text{ (m)}$$

A1

2

- (c) Correct use of  $W = \frac{1}{2}k\Delta L^2$  or  $\frac{1}{2}F\Delta L$

$$\Delta L = 5 \text{ m}$$

C1

Correct use of  $\Delta GPE = mg\Delta h$

$$\Delta h = 25 \text{ m}$$

C1

States or uses  $(mg\Delta h) - (\frac{1}{2} k\Delta L^2) = \frac{1}{2}mv^2$

C1

$$19 \text{ (m s}^{-1}\text{) cnao}$$

A1

4

- (d) Same kinetic energy when rope begins to stretch

B1

More work done per unit extension / stops in shorter distance

*"Shorter time" gets no credit*

B1

Increases force on jumper (increasing the risk of injury)

B1

3

[12]

6

- (a)  $8300 \times 9.81$  OR  $= 81423 \checkmark$

$$(8300 \times 9.81 \sin 25)$$

$$= 3.4 \times 10^4 \text{ (N)} \checkmark (34\,411 \text{ N}) \text{ ecf from first line unless g not used}$$

$m \sin 25$  gets zero

*Penalize use of  $g = 10$  here only*

$$(35\,077 \text{ N})$$

*Allow 9.8 in any question*

**Correct answer only, gets both marks for all two mark questions**

2

- (b) (i)  $(E_k = \frac{1}{2}mv^2)$

$$= \frac{1}{2} \times 8300 \times 56^2 \checkmark$$

$$= 1.3 \times 10^7 \text{ (J)} \checkmark (13\,014\,400) \text{ allow use of 8300 only}$$

*In general: Penalise transcription errors and rounding errors in answers*

2

- (ii)  $mgh = KE$  (13 014 400) for  $mgh$  allow GPE or  $E_p$   
 OR  $13\,014\,400 / 81\,423 \checkmark$   
 $h = 160$  (m)  $\checkmark$  (159.8) ecf 1bi  
*Allow use of suvat approach*

2

- (c) (i) (work done) by friction \ drag \ air resistance \ resistive forces  $\checkmark$   
 (energy converted) to internal \ thermal energy  $\checkmark$   
*Allow 'heat'*

2

- (ii)  $0.87 \times (8300 \times 9.81 \times 140 = 9\,917\,000)$  OR  $v = \sqrt{\frac{2 \times (9\,917\,000)}{8300}} \checkmark$   
 $= 49$  ( $= 48.88 \text{ ms}^{-1}$ )  $\checkmark$   
*87% of energy for 140m or 160m only for first mark.*  
*Use of 160 (52.26) and / or incorrect or no % (52.4) gets max 1*  
*provided working is shown*  
**Do not credit suvat approaches here**

2

[10]

7

- (a) (i) ( $s = \frac{1}{2}(u + v) t$ )  $t = 2s/v \checkmark$  (correct rearrangement, either symbols or values)  
 $(= 100/6.7) = 15 \checkmark$  (s) (14.925)  
 or alternative correct approach

2

- (ii) ( $KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 83 \times 6.7^2$ )  $= 1900 \checkmark$  (1862.9 J)  
**2 sf**  $\checkmark$

2

- (iii) GPE  $= 83 \times 9.81 \times 3.0 \checkmark$  penalise use of 10, allow 9.8  
 $= 2400$  (2443 J)  $\checkmark$  do not allow 2500 (2490) for use of  $g = 10$

2

- (b) (i)  $5300 + 3700$  (or 9000 seen)  
**or**  $- 2443 - 1863$  (or  $(-)$  4306 seen)  $\checkmark$   
 $= 4700$  (J)  $\checkmark$  (4694) ecf from parts aii & aiii

2

(ii) mention of friction and appropriate location given ✓

mention of **air** resistance (or drag) ✓

do not allow energy losses or friction within the motor

do not allow energy losses from the cyclist

must give a **cause** not just eg 'heat loss in tyres'

2

[10]

8

(a)  $PE = mgh$

C1

$$= 41 \times 9.8 \times 3.0 =$$

$$1200 \text{ or } 1210 \text{ J}$$

A1

2

(b) (i)  $mgh = 0.5mv^2$

C1

$$v = 7.7 \text{ ms}^{-1}$$

A1

2

*or ecf from (a)*

(ii)  $F = mg \cos 50$

C1

$$= 258 \text{ N}$$

A1

2

[6]

9

(a)  $\frac{1}{2} \times (70 \times 9.8) \times 35$

M1

$$= 1.2 \times 10^4 \text{ J}$$

A1

2

(b) use of  $mg\Delta h$

C1

$$= 70 \times 9.8 \times 85$$

C1

$$= 58.3 \times 10^3 \text{ J}$$

A1

3

[5]

10

C

[1]

11

(a) (i)  $65 \times 9.8 \times 35$  seen and evaluated to 22295 or 2231 or 22300J

B1

(ii) correct substitution of 65 kg and either 11000J or  $18 \text{ m s}^{-1}$  in ke formula seen

B1

18.4 (18.397) ( $\text{m s}^{-1}$ ) to at least 3 sf

B1

(iii) distance = energy loss/force or work done/force or numerical equivalent

C1

64-64.3 using  $E_p = 20\text{kJ}$  or 79 – 81(m) using 22.3 kJ

A1

(iv) friction

B1

air resistance

B1

further detail eg friction at ski-ice surface

or caused by need to move air when passing through it

B1

(b) (i) time =  $\Delta v/a$  or numerical equivalent

C1

$$6.4(3) - 6.6(6.57) \text{ (s)}$$

A1

(ii) use of appropriate kinematic equation

C1

$$(57.8 - 60.4) \text{ 58 m or 60 (m) to 2 sf}$$

A1

4

[12]

12

correct boxes ticked

gravitational potential energy **(1)**

B1

potential energy **and** kinetic energy **(1)**

B1

elastic potential energy ( in 'rope' ) **(1)**  
(condone gravitational PE in addition)

B1

[3]

13

(a) (i)  $(m = \rho V) = 1.2 \times 3.5 \times 10^5$  must be seen **(1)**

$$4.2 \times 10^5 \text{ (kg) seen (1)}$$

2

$$(ii) \quad (E_k = \frac{1}{2} mv^2) = \frac{1}{2} \times 4.2 \times 10^5 \times 11^2 \text{ (1)}$$

$$2.5 \text{ or } 2.4 \times 10^7 \text{ (J) (1) (25.4 or 24.2 MJ)}$$

2

$$(iii) \quad \frac{10 \times 10^6}{2.54 \times 10^7} \text{ (1) allow ecf from (a) (ii)}$$

39 to 41.6 (%) **(1)** allow ecf from (a) (ii) unless percentage is greater than 100

2

(b) **advantages**, any one:

wind has: no fuel cost/causes no air pollution/no CO<sub>2</sub>/is renewable **(1)**

**disadvantages**, any one from:

wind: varies/is intermittent/unreliable/causes visual pollution/noise/  
danger to birds/has a high capital cost/high 'start up' cost/requires  
changes to National Grid need **(1)** allow 'unpredictable'