Access Tuition

A-Level Physics

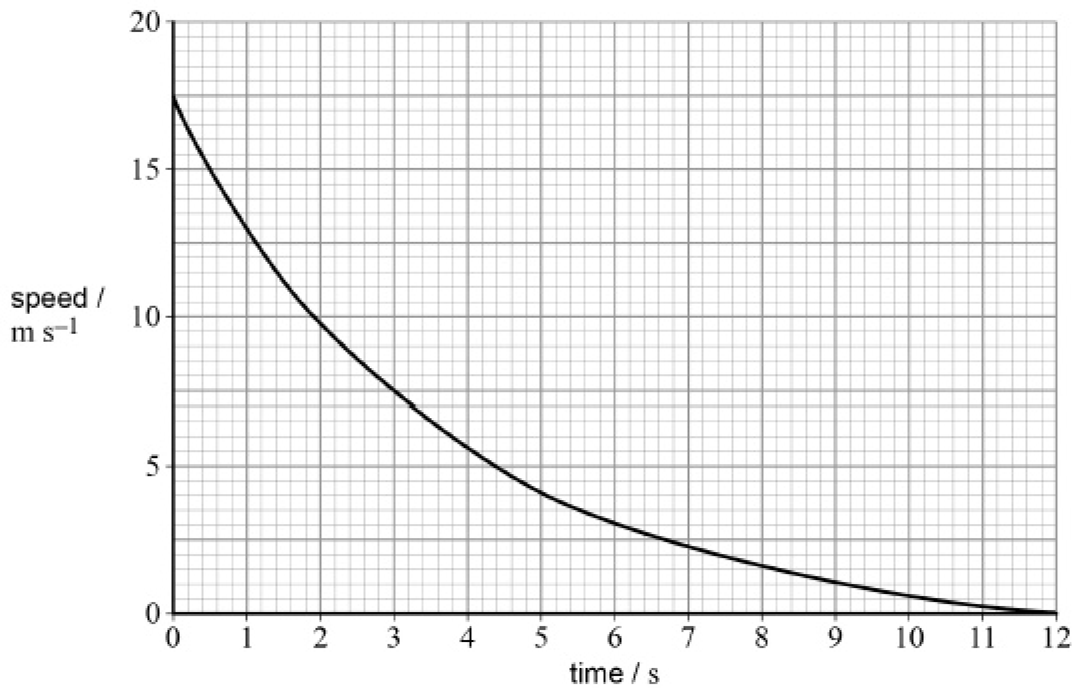
Work, Energy and Power

Question Paper

Time available: 66 minutes
Marks available: 53 marks

1. Horizontal escape lanes made of loose gravel have been constructed at the side of some roads on steep hills so that vehicles can stop safely when their brakes fail.

The graph shows an engineer's prediction of how the speed of an unpowered vehicle of mass 1.8×10^4 kg will vary with time as the vehicle comes to rest in an escape lane.



(a) Determine the force decelerating the vehicle 2.0 s after entering the escape lane.

force decelerating the vehicle = ____________________ N

(3)

(b) Deduce whether a lane of length 85 m is long enough to stop the vehicle, assuming that the engineer’s graph is correct.

____

____

(3)

(c) Discuss the energy transfers that take place when a vehicle is decelerated in an escape lane.

____

____

____

____

____

____

____

____

____

(2)

(d) An alternative to an escape lane containing gravel is an escape lane that consists of a ramp. An escape ramp is a straight road with a concrete surface that has a constant upward gradient.

One escape ramp makes an angle of 25° to the horizontal and is 85 m long.

Deduce whether this escape ramp is sufficient to stop the vehicle.

Assume that any frictional forces and air resistance that decelerate the vehicle are negligible.

____

____

(3)

(e) Discuss whether an escape lane containing gravel or an escape ramp would provide the safer experience for the driver of the vehicle as it comes to rest.

____

____

____

____

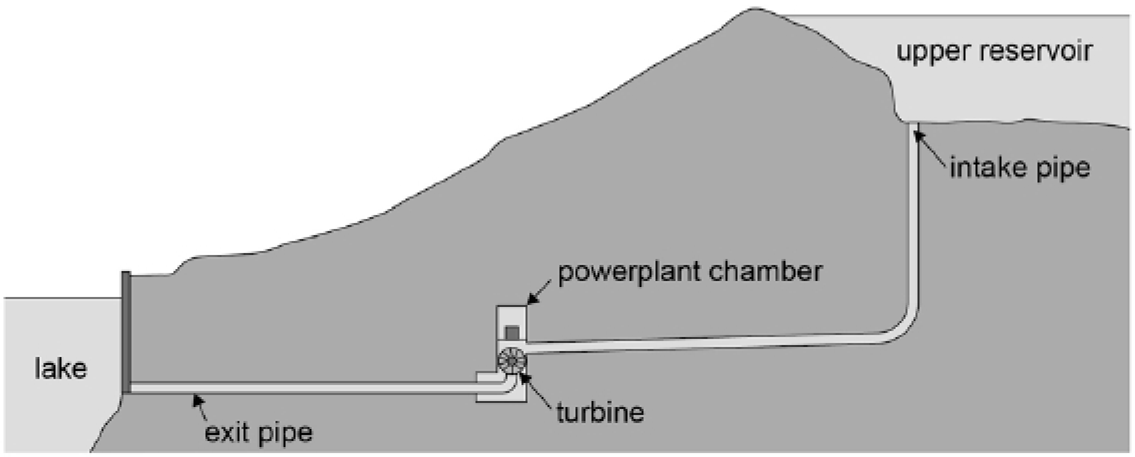
____

____

(1)

(Total 12 marks)

2. 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 m s^{-1}.

(2)

(b) The volume of water flowing into the turbine every second is 3.5 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 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 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. ____

____

____

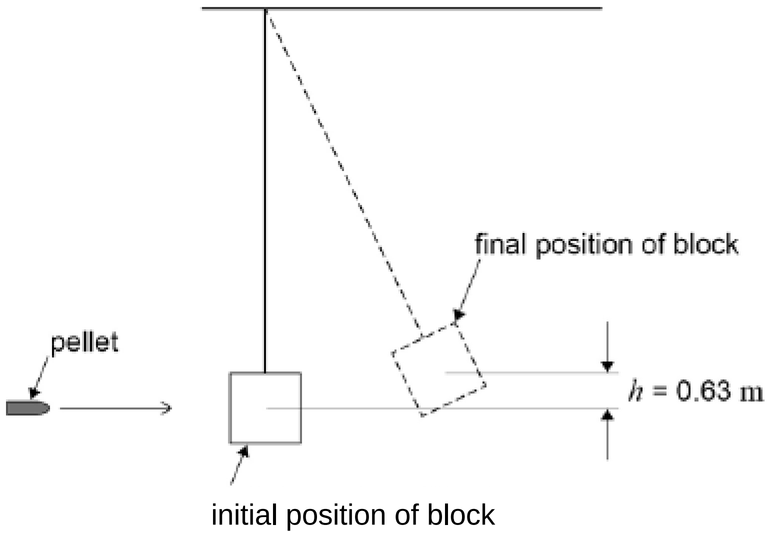
2. ____

____

____

(2)
(Total 10 marks)

3. The speed of an air rifle pellet is measured by firing it into a wooden block suspended from a rigid support.
The wooden block can swing freely at the end of a light inextensible string as shown in the figure below.



A pellet of mass 8.80 g strikes a stationary wooden block and is completely embedded in it. The centre of mass of the block rises by 0.63 m. The wooden block has a mass of 450 g.

(a) Determine the speed of the pellet when it strikes the wooden block.

speed = ____________________ m s^{-1}

(4)

(b) The wooden block is replaced by a steel block of the same mass.
The experiment is repeated with the steel block and an identical pellet. The pellet rebounds after striking the block.

Discuss how the height the steel block reaches compares with the height of 0.63 m reached by the wooden block. In your answer compare the energy and momentum changes that occur in the two experiments.

____

____

____

____

____

____

____

____

____

____

(4)

(c) Discuss which experiment is likely to give the more accurate value for the velocity of the pellet.

____

____

____

____

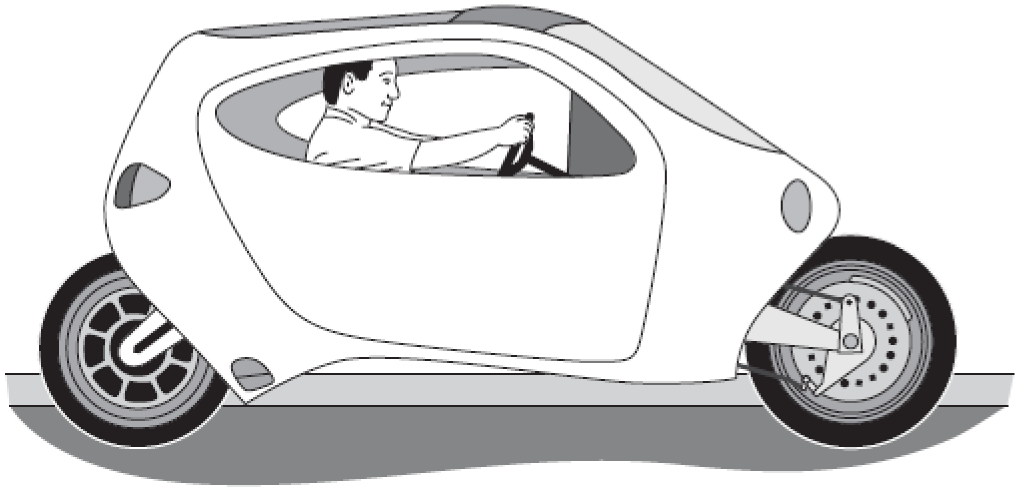
____

____

(2)

(Total 10 marks)

4. The diagram below shows an electric two-wheeled vehicle and driver.



(a) The vehicle accelerates horizontally from rest to 27.8 m s^{-1} in a time of 4.6 s. The mass of the vehicle is 360 kg and the rider has a mass of 82 kg.

(i) Calculate the average acceleration during the 4.6 s time interval.
Give your answer to an appropriate number of significant figures.

acceleration = ____________________ m s^{-2}

(2)

(ii) Calculate the average horizontal resultant force on the vehicle while it is accelerating.

resultant force = ____________________ N

(2)

(b) State and explain how the horizontal forward force on the vehicle has to change for **constant** acceleration to be maintained from 0 to 27.8 m s^{-1}.

____

____

____

____

____

____

____

____

(3)

(c) The electric motors drive both wheels of the vehicle.

Add labelled force arrows to the diagram to show the horizontal forces acting on the vehicle when it is moving at a constant speed.

(2)

(d) The vehicle now accelerates to a constant speed of 55 m s^{-1}. The useful power output of the motors is 22 kW at this speed.

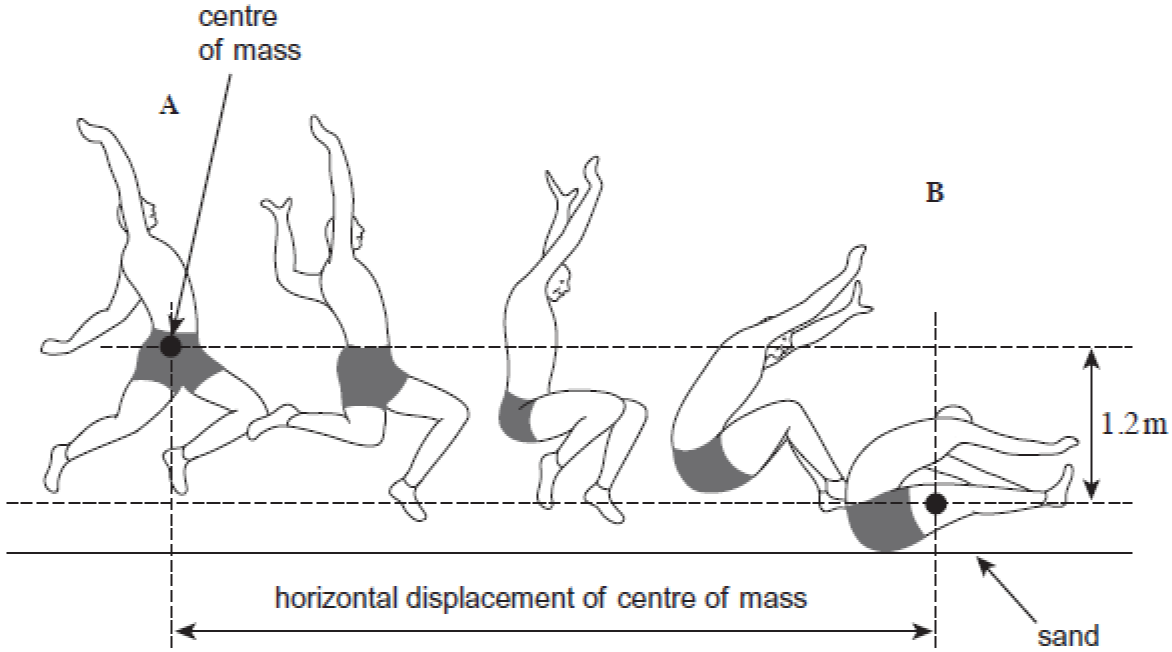
Calculate the horizontal resistive force acting on the vehicle.

horizontal resistive force = ____________________ N

(2)

(Total 11 marks)

5. The motion of a long jumper during a jump is similar to that of a projectile moving under gravity. The figure below shows the path of an athlete above the ground during a long jump from half-way through the jump at position **A**, to position **B** at which contact is made with sand on the ground. The athlete is travelling horizontally at **A**.



(a) During this part of the jump, the centre of mass of the athlete falls 1.2 m.

(i) Calculate the time between positions **A** and **B**.

time ____________________ s

(3)

(ii) The athlete is moving horizontally at **A** with a velocity of 8.5 m s^{-1}. Assume there is noair resistance. Calculate the horizontal displacement of the centre of mass from **A** to **B**.

horizontal displacement ____________________ m

(2)

(b) (i) The athlete in the image above slides horizontally through the sand a distance of 0.35 m before stopping.

Calculate the time taken for the athlete to stop. Assume the horizontal component of the resistive force from the sand is constant.

time ____________________ s

(2)

(ii) The athlete has a mass of 75 kg. Calculate the horizontal component of the resistive force from the sand.

horizontal component of resistive force ____________________ N

(3)

(Total 10 marks)