1

The photograph shows a lawnmower being used to cut grass.

(a) (i) In order to push the lawnmower, a minimum force of 650 N must be applied to the handle of the lawnmower at an angle of 42° to the horizontal.

Show that the horizontal component of the force is about 500 N.

(2)

....

....

....

....

(ii) The lawnmower is used to cut 15 strips of grass, each 7 m long.

Calculate the work done by the person pushing the lawnmower.

(2)

....

....

....

....

Work done ....

(b)

This photograph shows a lawnmower with the top section of the handle horizontal.

Explain how this changes the minimum force required to push the lawnmower.

(2)

....

....

....

....

....

(Total for Question 6 marks)

2 The photograph shows a wind turbine. Kinetic energy of the wind is transferred to electrical energy by the turbine as the blades rotate.

(a) Explain why we can say that the wind is doing work on the blades.

(2)

....

....

....

....

(b) The area swept out by one blade, as it turns through 360°, is 6000 m^2. Wind at a speed of 9 m s^{1} passes the turbine.

(i) Show that the volume of air passing through this area in 5 seconds is about 300 000 m^3.

(2)

....

....

....

(ii) Calculate the mass of this air.

density of air   1.2 kg m ^{3}

(2)

Mass ....

(iii) Calculate the kinetic energy of this mass of air.

(2)

Kinetic energy ....

(iv) Betz's law states that a turbine cannot usefully transfer more than 59% of the kinetic energy of the wind.

Use this law to find the maximum power output of the wind turbine.

(2)

Maximum power ....

(c) Suggest a reason why it is not possible to usefully transfer 100% of the kinetic energy of the wind.

(1)

....

....

....

....

(d) Suggest the limitations of using wind turbines to provide power.

(2)

....

....

....

....

....

....

(Total for Question 13 marks)

3 One account of the origin of the term *horsepower* is as follows.

In the eighteenth century, James Watt manufactured steam engines. He needed a way to demonstrate the benefits of these compared to the horses they replaced. He did some calculations based on horses walking in circles to turn a mill wheel.

Watt observed that a horse could turn the wheel 144 times in one hour. The horse travelled in a circle of radius 3.7 m and exerted a force of 800 N.

(a) Show that the work done by the horse in turning the wheel through one revolution was about 20 000 J.

(3)

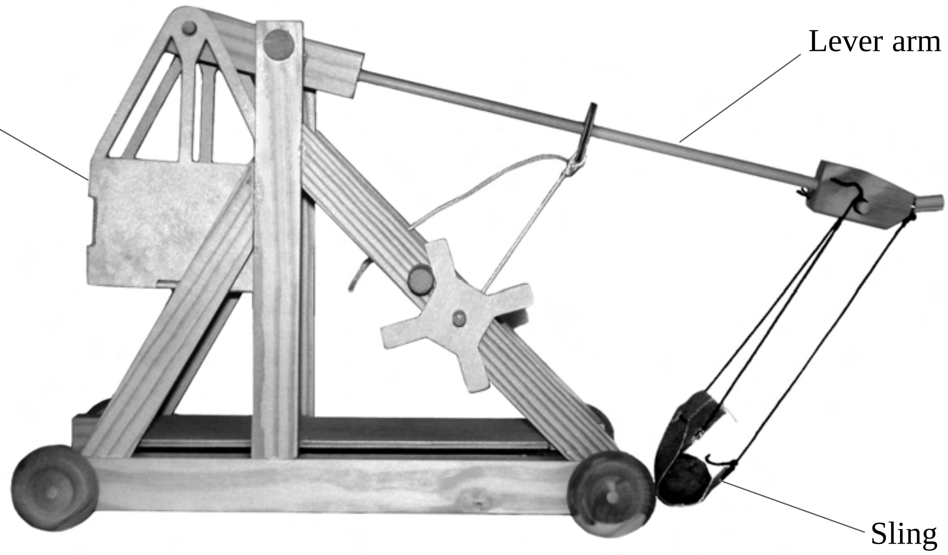
(b) Calculate the average power of the horse in SI units.

(3)

Average power =

(Total for Question = 6 marks)

***4** The photograph shows a model of 'Warwolf', a siege engine used in the thirteenth century. It was used to attack castles by firing missiles from a sling.



To operate this model, coins are placed in the basket and a small projectile is placed in the sling. When the basket is released, it falls quickly, swinging the lever arm up and shooting the projectile from the sling.

(a) On one occasion the mass of coins placed in the basket is 0.41 kg. The basket falls through a vertical distance of 7.0 cm.

Calculate the maximum amount of energy available to launch the projectile.

(2)

Energy =

(b) An energy conversion calculation predicts a projectile speed of 16 m s^{-1}. The projectile is observed to fly out of the sling at an angle of 40° to the horizontal.

Resolve this velocity into horizontal and vertical components.

(3)

Horizontal component =

Vertical component =

(c) The predicted range is 27 m. When measured, the range is found to be only 8 m.

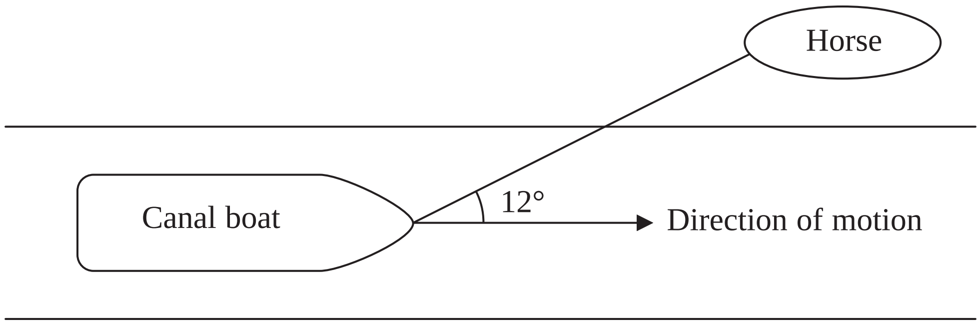
Air resistance and friction in the machine are possible reasons for the difference.

Without further calculation, explain another reason why the projectile does not go as far as predicted.

(2)

(Total for Question = 7 marks)

5



A horse is pulling a canal boat using a rope at 12° to the direction of motion of the boat. The tension in the rope is 1150 N.

(a) The canal boat is moving at a steady speed. Calculate the resistive force opposing the boat's forward motion.

(2)

....

....

Force = ...

(b) Calculate the work done on the boat by the horse when the canal boat is towed 500 m along the canal.

(2)

....

....

Work = ...

(c) Explain why using a longer rope could allow the horse to do the same work while producing a lower tension in the rope.

(2)

....

....

....

(Total for Question = 6 marks)

6 The ‘Stealth’ roller coaster at the Thorpe Park theme park is advertised as reaching 135 km hour^{-1} from rest in 2.3 seconds.

Most roller coasters are driven slowly up to the top of a slope at the start of the ride. However the carriages on ‘Stealth’ are initially accelerated horizontally from rest at ground level by a hydraulic launch system, before rising to the top of the first slope.

(a) (i) Calculate the average acceleration of the carriages.

135 km hour^{-1} = 37.5 m s^{-1}

(2)

Average acceleration =

(ii) Calculate the minimum average power which must be developed by the launch system.

mass of carriages and passengers = 10 000 kg

(3)

Minimum average power =

(iii) Suggest why the power in (ii) is a minimum value.

(1)

*(b) The force required to launch ‘Stealth’ is not always the same. The ride is monitored and the data from preceding launches is used to calculate the required force.

If the mass of the passengers for a particular ride is significantly more than for preceding launches, this can lead to ‘rollback’. This is when the carriages do not quite reach the top of the first slope and return backwards to the start.

Explain why ‘rollback’ would occur in this situation.

(3)

(c) Suggest why roller coasters may have a greater acceleration when the lubricating oil between the moving parts has had time to warm up.

(2)

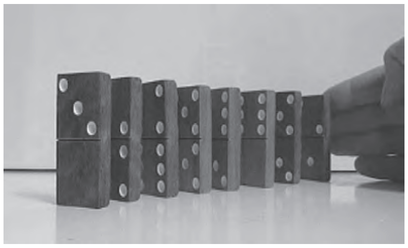
(Total for Question = 11 marks)

7 A teacher sets up two experiments for her students to complete.

The outcome of each experiment can be explained using Newton's laws.

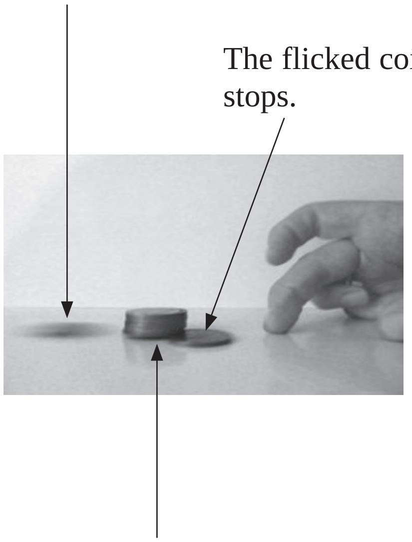
(a) Use Newton's first law of motion to explain the behaviour of the dominoes in experiment 1.

(2)

Experiment 1	Explanation
Falling dominoes The first domino is given a gentle push.  **Observation** The domino falls, knocking the next domino; one by one the dominoes fall. 	

*(b) Apply Newton’s laws of motion to explain the three observations in experiment 2.

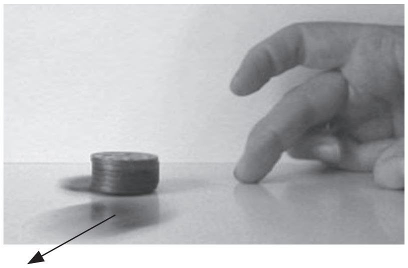
(6)

Experiment 2	Explanation
Stacked coins A coin is flicked towards a stack of coins.  **Observations** The bottom coin is knocked out from under the stack. The flicked coin stops.  The stack drops down.	

(c) Whilst carrying out the stacked coins experiment, the student sometimes observed that the flicked coin did not stop but changed its direction of travel.

Suggest a reason for this observation.

(2)

Observation	**Reason**
 The coin that was flicked changes its direction.	

(Total for Question = 10 marks)