1 The world's tallest building is the Burj Khalifa in Dubai, UAE.

The viewing gallery for the public is on the 124th floor. The lift that visitors use takes 56 seconds to reach this floor. The motion of the lift can be divided into three parts:

- acceleration
- constant velocity of 10 m s^{-1}
- deceleration.

(a) Draw a free-body force diagram for the forces acting on a passenger as the lift rises.

(2)

(b) A physics student of mass 60 kg decides to measure the initial acceleration of the lift. She places a set of scales on the floor of the lift and steps onto them. Whilst the lift is accelerating upwards the reading on the scales increases to 73 kg.

(i) Show that the initial acceleration of the lift is about 2 m s^{-2}.

(3)

(ii) Near the end of the ascent, the velocity of the lift decreases from 10 m s^{-1} to rest in 5.3 seconds.

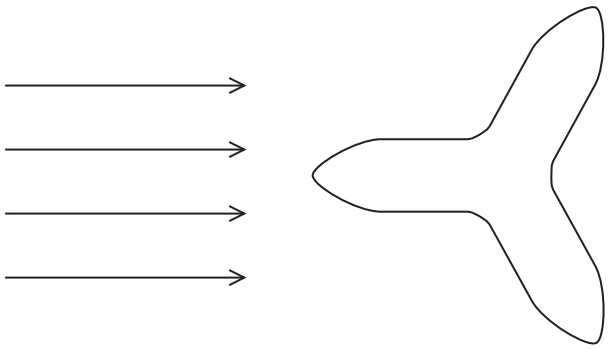
Calculate the deceleration.

(2)

Deceleration =

(c) The effects of the wind had to be considered in the position and design of the building, due to its height. It has been shaped, as in the diagram, so that the wind deflects around the building in a way which minimises turbulence.

Aerial view of the Burj Khalifa building

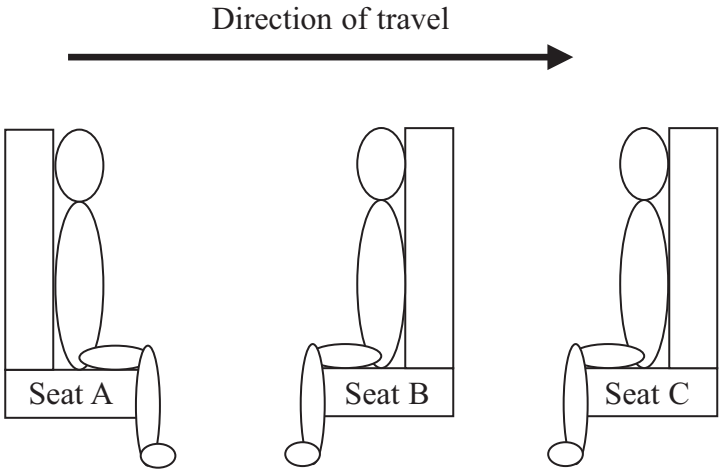


Add to the diagram above to show the air flow around the building, labelling regions of laminar and turbulent flow.

(2)

(Total for Question = 9 marks)

***2**



The diagram shows three passengers sitting on a train that is travelling at a high speed in the direction shown. Seat belts are not used on trains.

With reference to one of Newton's laws of motion, explain why seat C is the safest seat for a passenger to be sitting on in the event of a rapid deceleration. You may assume that the seats all remain fixed firmly to the floor and do not break.

(Total for Question 4 marks)

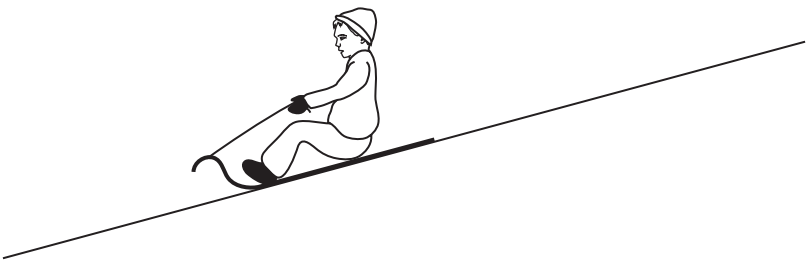
***3** During a lesson on Newton's laws of motion, a student says, "We don't really need to bother with Newton's first law because it is included in his second law".

State Newton's first two laws of motion and explain how Newton's second law includes the first law.

(5)

(Total for Question 5 marks)

4 (a) A child is going down a snowy hill on a sledge.



Complete, in the space below, a free-body force diagram for the child and sledge. Treat the child and sledge as a single body object.

(2)

(b) The child and sledge are pulled across level ground by an adult.

(i) They are pulled 11 m from rest in 4.9 s.

Show that the average acceleration is about 1 m s ^{2}.

(2)

(ii) The child and sledge have a combined mass of 40 kg.

Calculate the average resultant force on the child and sledge.

(2)

(c) The force applied by the adult is 200 N at an angle of 20° to the horizontal.

(i) Calculate the average resistive force acting while the sledge is being pulled.

(2)

Average resistive force .....

(ii) Calculate the average power developed by the adult in pulling the sledge 11 m.

(3)

Average power .....

(Total for Question 11 marks)

5 The Saturn V rocket used in NASA's space programme had a mass of 3.04×10^6 kg. It took off vertically with a thrust force of 3.40×10^7 N.

(a) Show that the resultant force on the rocket is about 4×10^6 N.

(3)

(b) Calculate the initial acceleration.

(2)

Initial acceleration = ...

(c) After 150 s the rocket reached a speed of 2390 m s^{-1}.

Calculate its average acceleration.

(2)

Average acceleration = ...

(d) Suggest why the initial acceleration and average acceleration are different.

(1)

(Total for Question = 8 marks)

6 (a) What is meant by Newton's first law of motion?

(2)

.....

.....

(b) Newton's third law identifies pairs of forces.

(i) State **two** ways in which the forces in a pair are identical.

(2)

.....

.....

(ii) State **two** ways in which the forces in a pair differ.

(2)

.....

.....

(iii) One of the forces acting on a car can be described as follows:

'The Earth exerts a downward gravitational force of 12 000 N on the car'.

Describe its Newton's third law pair force.

(2)

.....

.....

(Total for Question = 8 marks)

*** 7** You are asked to determine the acceleration of free fall at the surface of the Earth, g, using a free fall method in the laboratory.

(a) Describe the apparatus you would use, the measurements you would take and explain how you would use them to determine g.

(6)

(b) Give **one** precaution you would take to ensure the accuracy of your measurements.

(1)

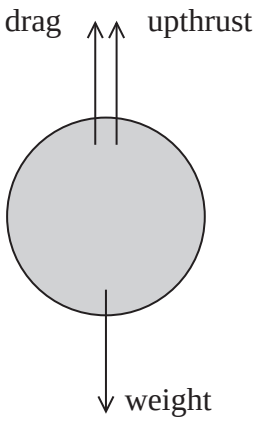
(Total for Question = 7 marks)

8 The Greek philosopher Aristotle (4th Century BC) stated that heavy objects fall more quickly than lighter objects.

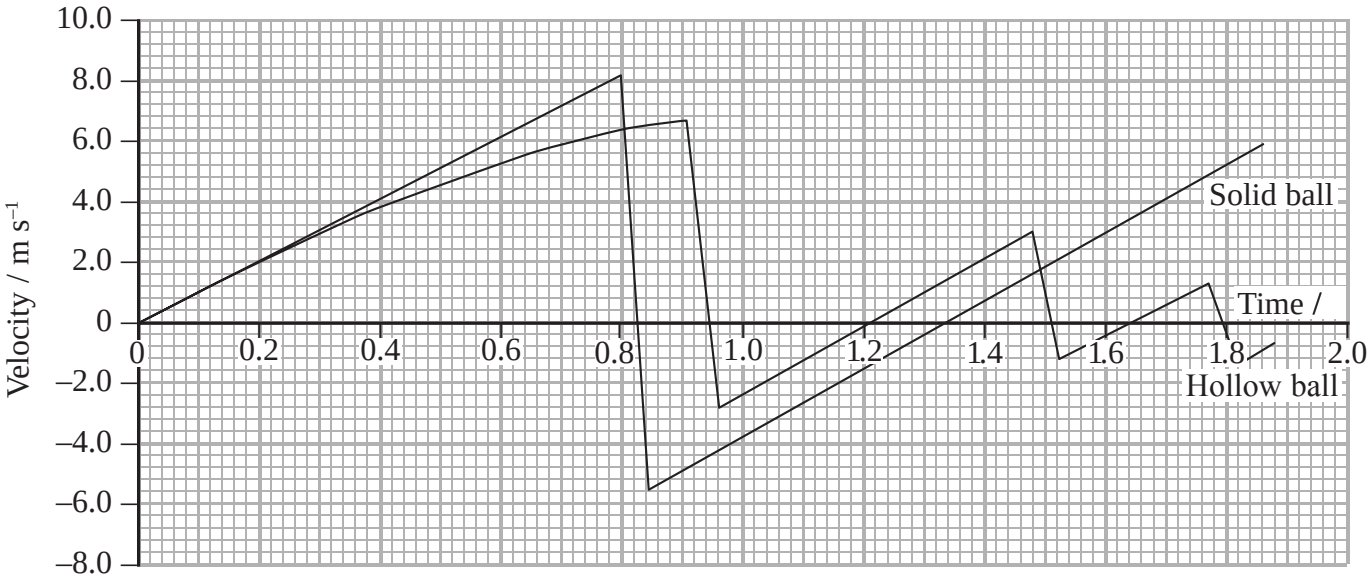
In the 17th Century Galileo reported that a cannon ball and a much smaller musket ball, dropped at the same time, reached the ground together.

A student carries out an experiment, dropping two balls of the same size at the same time. One of the balls is hollow and the other is solid.

The diagram shows the forces acting on each ball as it falls.



The velocity-time graph shows the motion of the two balls from the time they are dropped.



(a) State how the graphs show that neither ball reaches terminal velocity.

(1)

(b) (i) By drawing a tangent to the graph, show that the acceleration of the hollow ball at time $t = 0.60$ s is about $7\,\text{ms}^{-2}$.

(2)

(ii) Show that the resultant force on the hollow ball at $t = 0.60$ s is about 0.02 N.

mass of hollow ball = 2.4 g

(2)

(iii) Show that the drag force on the hollow ball at $t = 0.60$ s is about 0.01 N. You may neglect upthrust.

(2)

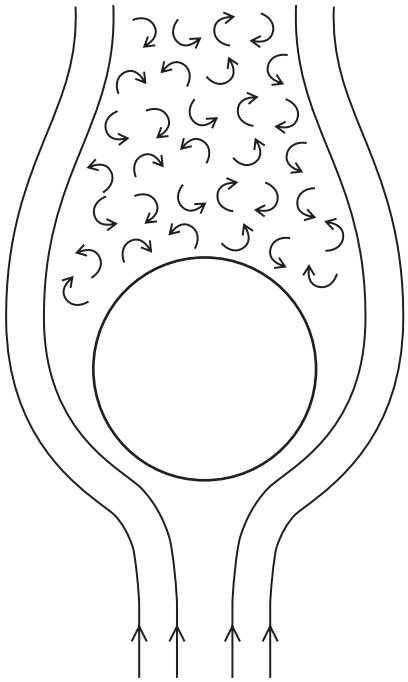
(iv) Demonstrate that the Stokes' law force is **not** sufficient to produce this drag force.

radius of hollow ball = 2.0 cm

viscosity of air = 1.8×10^{-5} Pa s

(2)

(c) The diagram shows the air flow around the hollow ball as it falls.



(i) Add labels to show laminar flow and turbulent flow.

(1)

(ii) Suggest why the drag is much greater than the Stokes' law force.

(1)

(d) Without further calculation, use the graph to describe the motion of the solid ball.

(3)

(Total for Question = 14 marks)