1 The gravitational field strength on the Moon is about 1/6 of the gravitational field strength on the Earth.

(a) On the Moon, an astronaut dropped a golf ball. He later wrote "When I dropped the ball, it took about three seconds to land."

Show that the astronaut would need to be over 7 m tall for the ball to take 3 s to land.

(2)

(b) The astronaut hit the ball with a golf club. He wrote "The ball, which would have gone thirty to forty yards on the Earth, went over two hundred yards. The ball stayed up in the black sky for almost thirty seconds."

Assume an initial velocity of 18 m s^{-1} at 34° to the horizontal.

(i) Show that the astronaut's suggested time of flight of 30 s is over twice the actual value.

(3)

(ii) Show that the value given for the initial velocity leads to a value for the horizontal distance travelled by the ball in agreement with his stated value.

200 yards = 183 m

(3)

*(c) A projectile would have a greater range on the Moon than the Earth because of the lower gravitational field strength and because of the lack of an atmosphere.

Explain how each of these factors would increase the range of the projectile.

(3)

(Total for Question = 11 marks)

2 A student carried out an experiment to obtain a value for the acceleration of free fall *g*.

A small ball was dropped from rest and the motion of the ball was captured using a digital camera. The student counted the frames from the recording to measure the time *t* for the ball to fall to the ground.

A ruler was visible on the recording to enable the student to measure the distance *s* fallen by the ball.

(a) Use Newton's second law of motion to show that the acceleration of the ball is independent of its mass.

(1)

(b) (i) State the equation that the student should use to calculate the value of *g*.

(1)

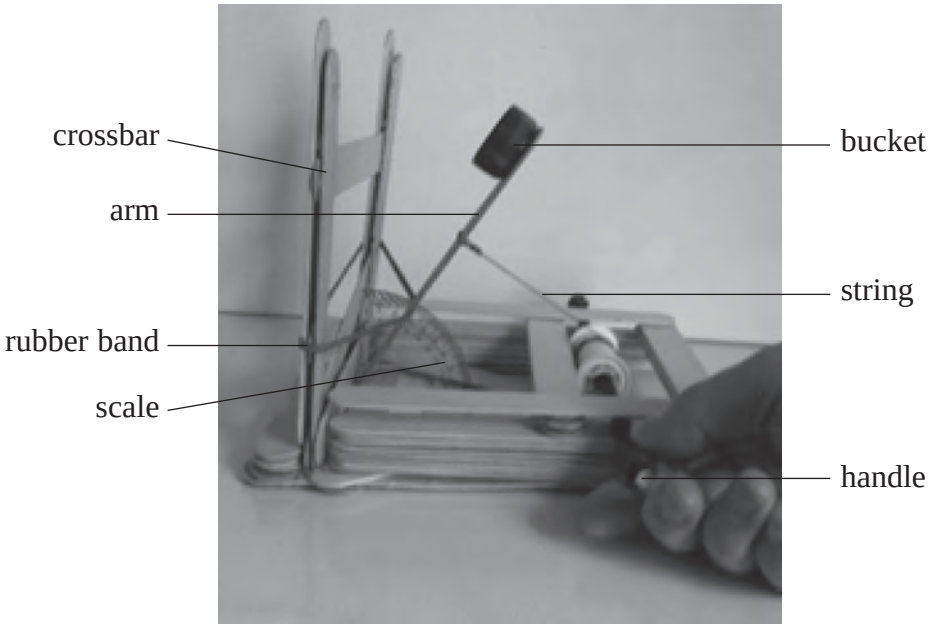
(ii) A value for *g* was obtained and was greater than expected.

Explain **one** possible source of error that would have produced a greater than expected value.

(2)

(Total for Question = 4 marks)

3 A Mangonel is a type of catapult used to launch projectiles such as rocks. A student made a working model of a Mangonel.



As the handle is turned, the arm is pulled back by the string. This increases the tension in the rubber band. When the string is released, the rubber band causes the arm to move upwards, launching a projectile from the bucket when the arm hits the crossbar.

(a) (i) Suggest why a rubber band is used to support the arm.

(1)

(ii) State the energy transfers that occur when the string is released.

(1)

(b) The student varied the angle to the vertical at which the arm was released. The range of the projectile was measured for each angle.

Release angle to the vertical / °	15	30	45	60
Mean range / m	0.14	0.58	0.95	1.70

*(i) Explain why the range increases as the angle increases.

(4)

(ii) The student replaces the projectile with one of a smaller mass.

State why this increases the range of the projectile.

(1)

(iii) Suggest one modification to the model that would also increase the range of the projectile. Give a reason for your answer.

(2)

Modification

Reason

(c) The student wishes to place a target in the path of the projectile. The height of the target is 5.0 cm. The projectile is released horizontally from a height of 13.0 cm.

(i) Show that the time taken for the projectile to fall to a height of 5.0 cm is about 0.1 s.

(2)

(ii) When the arm was pulled back through an angle of 60°, the time taken for the projectile to travel 1.7 m horizontally was 0.16 s.

Calculate the minimum horizontal distance that the target should be placed from the model for the projectile to hit it.

(3)

Minimum horizontal distance =

(Total for Question = 14 marks)

4 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.

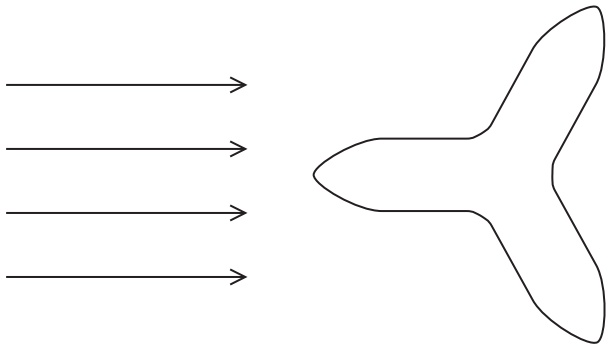
Calculate the deceleration.

(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



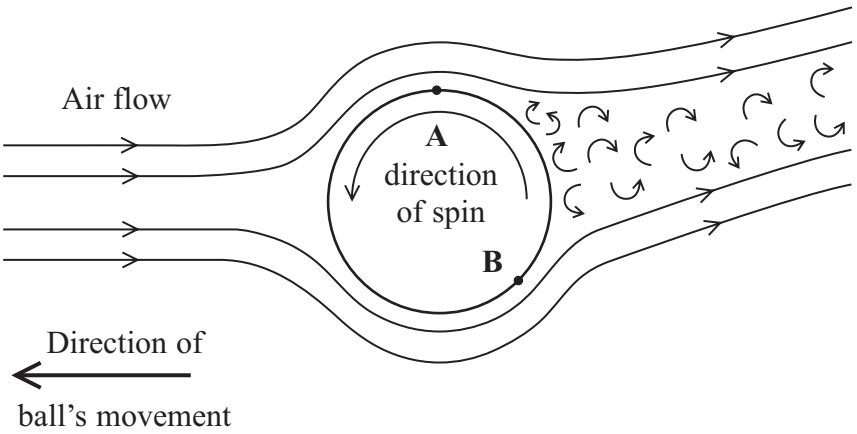
Add to the diagram above to show the air flow around the building, labelling regions of laminar and turbulent flow.

(2)

(Total for Question = 9 marks)

5 In the game of table tennis a ball is hit from one end of the table to the other over a small net.

(a) Making a table tennis ball spin when it is hit can affect its flight. The diagram shows the path of air around a spinning ball. It contains regions of laminar flow and turbulent flow. The flow changes from one to the other at points A and B.



(i) Explain what is meant by laminar flow and turbulent flow.

(2)

Laminar flow

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Turbulent flow

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(ii) The ball is spinning in the direction shown in the diagram.

Suggest why there is a larger region of turbulent flow on the top of the ball than the bottom.

(1)

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(b) The diagram shows that the air is deflected upwards after passing the ball.

Explain why this means there must be a downwards component of force on the ball in addition to its weight.

(2)

(c) Spinning a table tennis ball allows it to be hit harder and still hit the table on the other side of the net.

(i) A table tennis ball is hit, without any spin, from one end of a table so that it leaves the bat horizontally with a speed of 31 m s ^{1}. The length of the table is 2.7 m.

Show that the ball falls a vertical distance of about 4 cm as it travels the length of the table.

(3)

(ii) The net is 15 cm high. Explain how the spin helps the ball hit the table on the other side of the net.

(3)

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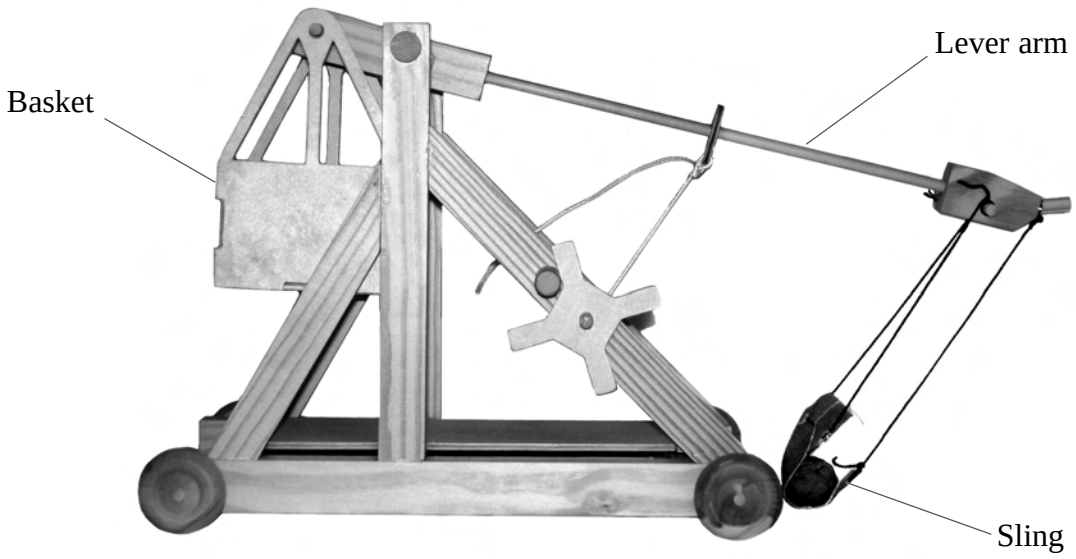
(Total for Question 11 marks)

*6 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)

7 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)

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(b) Calculate the initial acceleration.

(2)

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Initial acceleration = ...

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

Calculate its average acceleration.

(2)

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.....

Average acceleration = ...

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

(1)

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(Total for Question = 8 marks)