1 The picture shows a track for racing toy electric cars. A guide pin fits in a groove in the track to keep the car on the track. A small electric motor in the car is controlled, with a hand-controller, via contacts in the track.

A child places a car of mass 95 g on the track. She adjusts the controller to a power of 4.2 W so the car accelerates from rest for 0.40 s.

(a) (i) Show that the energy transferred by the motor in 0.40 s is about 2 J.

(2)

(ii) Calculate the speed of the car at 0.40 s.

(2)

Speed =

(iii) Suggest why the actual speed of the car is less than the calculated speed.

(1)

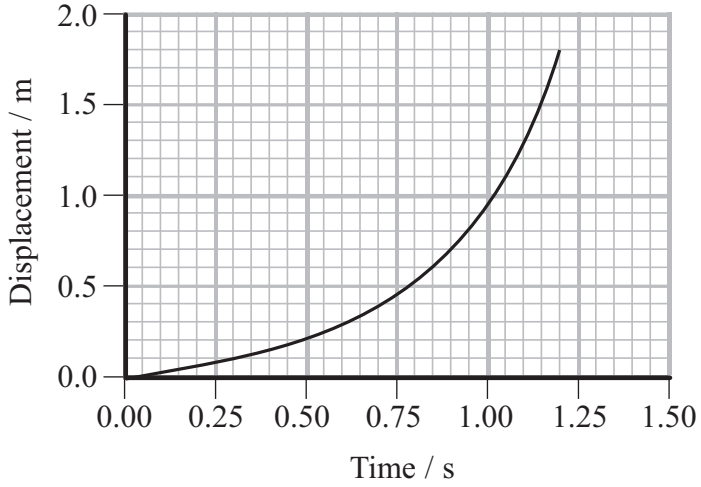
(b) At high speed the guide pin may become disengaged from the groove.

Use Newton's first law to explain why the car would then leave the track at a corner.

(2)

(Total for Question = 7 marks)

2 A small, gas-filled balloon was dropped from a height. The displacement-time graph for the balloon is shown.



As the displacement of the balloon from its point of release increased, gravitational potential energy was transferred to kinetic energy and thermal energy.

(a) State why the rate of energy transfer was greatest at 1.20 s.

(1)

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(b) By calculating the change in gravitational potential energy of the balloon between 1.05 s and 1.20 s, show that the average rate at which the gravitational potential energy was transferred during this time interval was about 0.2 W.

mass of balloon and air 0.004 kg

(3)

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(Total for Question 4 marks)

3 (a) State what is meant by work done.

(1)

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(b) A car of mass 1.5×10^3 kg is travelling on a country road towards a village at 55 miles per hour. The speed limit in the village is 30 miles per hour.

When the brakes are applied, there is a constant braking force of 3750 N.

Calculate the minimum distance before reaching the village that the driver should apply the brakes to avoid exceeding the speed limit.

55 miles per hour 24.6 m s ^{1}

30 miles per hour 13.4 m s ^{1}

(3)

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Minimum distance .....

(Total for Question 4 marks)

4 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.

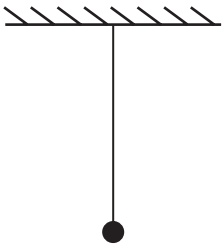
Explain how each of these factors would increase the range of the projectile.

(3)

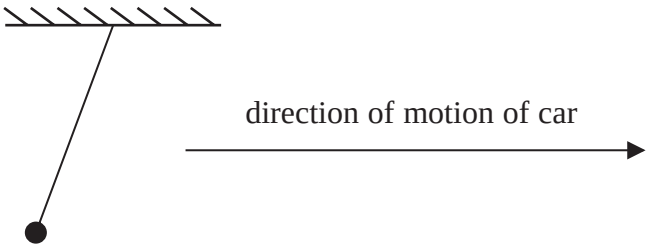
(Total for Question = 11 marks)

5 Many hand held devices such as smartphones and tablet computers contain accelerometers. These allow changes in orientation of the device to be tracked.

A student models a simple accelerometer by attaching a small mass on a string to the roof of a car.



When the car starts moving, the string is seen to change position as shown below.



(a) (i) Complete a free body force diagram for the mass when the car starts moving.

(2)

(ii) Draw a vector diagram, in the space below, to show how the resultant force on the mass is produced.

(2)

(iii) When the string is at 7° to the vertical, show that the acceleration of the car is about 1 m s^{-2}.

(2)

(b) Sketch the positions of the mass and string when the car is moving in the same direction and is:

(i) moving with constant velocity,

(ii) undergoing a much greater acceleration than in (a)(iii),

(iii) decelerating.

(3)

(i) moving with constant velocity,

(ii) undergoing a much greater acceleration than in (a)(iii),

(iii) decelerating.

(c) Explain why the string would **not** become horizontal, however great the acceleration.

(2)

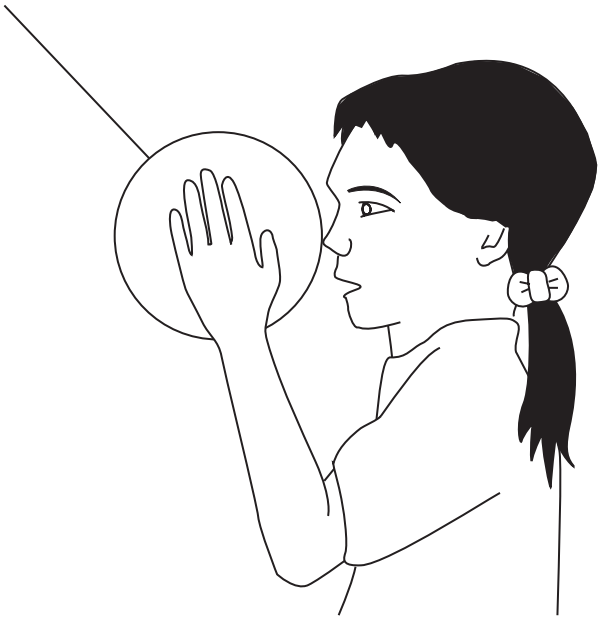
(d) Suggest why many devices contain 3 accelerometers, arranged at right angles to each other.

(1)

(Total for Question = 12 marks)

*6 In a demonstration of energy transfer, a large pendulum is made by suspending a 7.0 kg bowling ball on a long piece of wire.

A student is invited to pull the ball back until it just touches her nose and then to release it and stand perfectly still while waiting for the ball to return.



The following instructions are given:

> Do not push the ball – just release it.
> Do not move your face before the ball returns.

(a) Explain this demonstration and the need for these instructions.

(6)

(b) The bowling ball is raised through a vertical distance of 1.5 m.

(i) Calculate the gravitational potential energy gained by the ball.

(2)

Gravitational potential energy =

(ii) Calculate the speed of the ball at the bottom of its swing.

(2)

Speed =

(Total for Question = 10 marks)

7 In 2008 a new energy scheme opened on the Scottish island of Eigg. The scheme uses solar, hydroelectric and wind energy. There are also stand-by diesel generators.

(a) In a feasibility study, the following information was collected about one possible hydroelectric site:

mean rate of water flow into turbine = 0.13 $m^3 s^{-1}$
change in height of water = 30 m.

(i) Show that the power available to the turbine is about 40 kW.

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

(3)

(ii) The study suggests a typical output for the turbine might be only 6 kW. Suggest a reason for this inefficiency.

(1)

(b) Publicity for the scheme states:

> "The whole project involves one 100 kW hydroelectric system, two smaller 6 kW hydroelectric systems, a 24 kW wind farm and a 10 kW solar energy system. There are also two 80 kW diesel generators on stand-by."

(i) Calculate the maximum energy output from the solar energy system for a period of six hours.

(2)

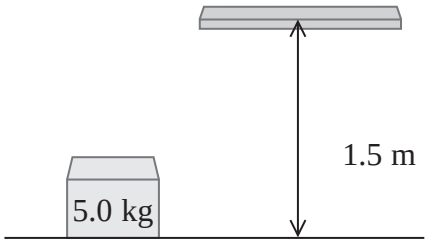
Maximum energy output =

(ii) Discuss the suitability of the output of the stand-by diesel generators.

(2)

(Total for Question = 8 marks)

8 A box of mass 5.0 kg is moved from the ground to a shelf at a height of 1.5 m.



A student is asked to calculate the energy transfer as the height is increased.

The student could use either of the following formulae.

$$\Delta W = F\Delta s \qquad \text{or} \qquad \Delta E_{grav} = mg\Delta h$$

(a) Explain how the two formulae are equivalent.

(2)

(b) Calculate the increase in gravitational potential energy of the box.

(2)

Increase in gravitational potential energy =

(Total for Question = 4 marks)