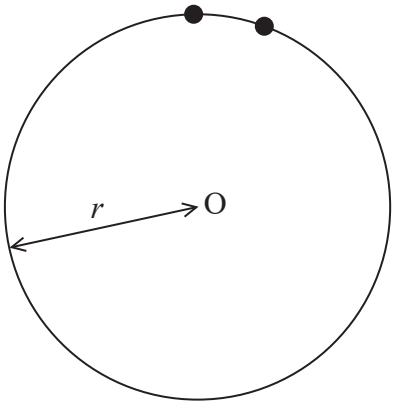
17 A centrifuge is a machine which rotates.

(a) A particle in a centrifuge moves in a circle of radius r, centre O, with a constant speed v.

The diagram represents two positions of the particle.

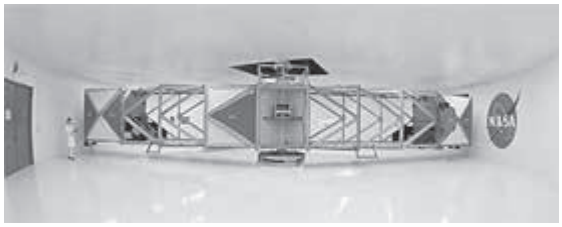


Derive the equation for centripetal acceleration $a = \frac{v^2}{r}$ by considering the velocity at these two positions.

Your answer should include a vector diagram.

(5)

(b) The United States' space agency, NASA, uses a centrifuge to test whether equipment will operate when experiencing large forces. The equipment to be tested is attached to the end of the frame of the centrifuge, which rotates around a vertical axis at its centre.



The centrifuge rotates at 50 revolutions per minute with a radius of 8.8 m.

(i) Show that the angular velocity of the centrifuge is about 5 rad s^{-1}.

(2)

(ii) Explain how the centrifuge applies large forces to the equipment under test.

(2)

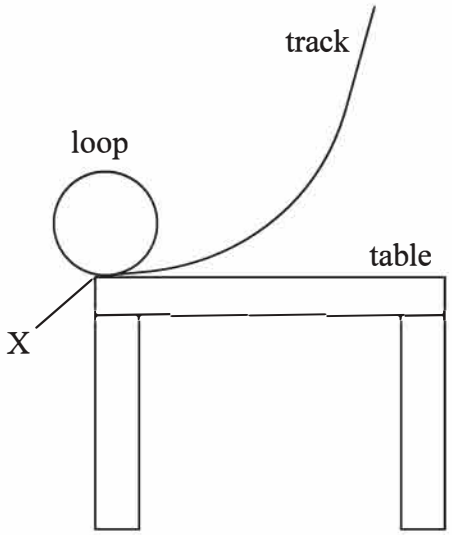
(iii) The NASA website says the centrifuge can be used to test whether the equipment can withstand accelerations of up to about 25*g*.

Deduce whether this claim is correct.

(2)

(Total for Question 17 = 11 marks)

11 A track for toy cars can be built with a circular loop as shown.



A toy car is placed on the track at various heights. It travels around the loop before leaving the track horizontally at X.

(a) The loop has radius r and the mass of the toy car is m. It is possible for a toy car to complete the loop without losing contact with the inside of the track.

For this to occur the minimum speed of the toy car at the top of the loop v_{top} is given by

$$v_{top} = \sqrt{gr}$$

Explain why.

(2)

(b) The toy car just completes the loop without losing contact with the track.

Show that the speed of the toy car at the bottom of the loop is about $3\,m\,s^{-1}$.

$r = 0.15\,m$

(3)

(c) The toy car leaves the track at X with a horizontal velocity of $3.0\,m\,s^{-1}$.

X is 0.65 m above the floor.

Calculate the horizontal displacement of the car from X when it hits the floor.

(4)

Horizontal displacement = ...

(Total for Question 11 = 9 marks)

7 The intensity of light incident on a light dependent resistor (LDR) can vary both its electrical resistance R and the number of charge carriers per unit volume n. The light intensity on an LDR is increased.

Which row of the table describes the effect on R and n?

	R	n
☒ **A**	decreases	decreases
☒ **B**	decreases	increases
☒ **C**	increases	decreases
☒ **D**	increases	increases

(Total for Question 7 = 1 mark)

8 A proton has a mass of 1.67×10^{-27} kg.

Which of the following shows the conversion of this mass to GeV/c^2 ?

☒ **A** $\dfrac{1.67 \times 10^{-27} \times 1.60 \times 10^{-10}}{(3.00 \times 10^{8})^2}$

☒ **B** $\dfrac{1.67 \times 10^{-27} \times 1.60 \times 10^{-19}}{(3.00 \times 10^{8})^2}$

☒ **C** $\dfrac{1.67 \times 10^{-27} \times (3.00 \times 10^{8})^2}{1.60 \times 10^{-10}}$

☒ **D** $\dfrac{1.67 \times 10^{-27}}{1.60 \times 10^{-10} \times (3.00 \times 10^{8})^2}$

(Total for Question 8 = 1 mark)

9 The blade of a lawnmower rotates at a speed of 50 revolutions per second.

Which of the following is the angular speed of the blade in rads s^{-1}?

☒ **A** 7.96

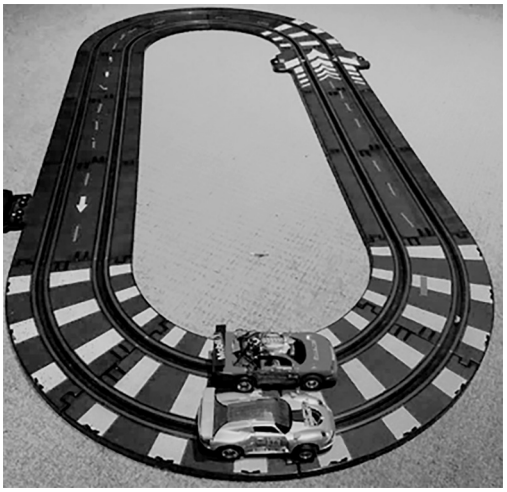
☒ **B** 15.9

☒ **C** 157

☒ **D** 314

(Total for Question 9 = 1 mark)

13 The photograph shows a model racing car set. The curved parts of the track are semicircular. The car makes electrical contact with the track using metal brushes underneath the car.



(a) There is a maximum speed for the car to stay on the curved part of the track. Explain why the car will slip off the curved part of the track if the car exceeds the maximum speed.

(3)

(b) The following measurements are made for a car starting at rest on a straight piece of track.

distance travelled = 1.2 m

time taken = 0.77 s

(i) Show that the final velocity of the car is about 3 m s^{-1}.

Assume the acceleration is constant.

(2)

(ii) The final velocity calculated in (b)(i) is the maximum velocity before the car slips off the track.

Calculate the maximum horizontal force between the curved part of the track and the car.

mass of car = 0.050 kg

radius of curved part of track = 0.042 m

(2)

Maximum horizontal force = ...

(c) The cars are controlled separately and so can be raced, with one car on the inner lane and the other on the outer lane. The cars are identical. Each car is raced at its highest speed for that lane.

Explain why the outcome of the race is difficult to predict.

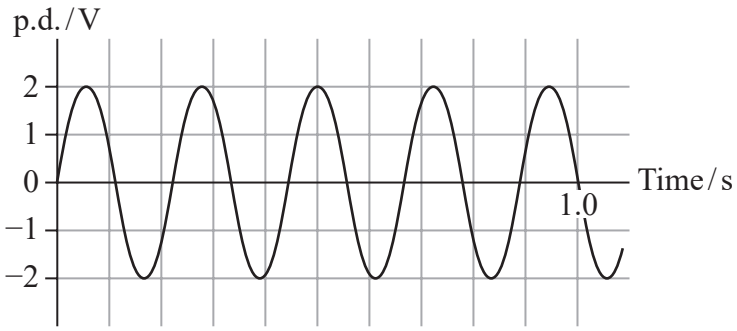
(3)

(Total for Question 13 = 10 marks)

Answer ALL questions.

All multiple choice questions must be answered with a cross ☒ in the box for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The graph shows how a potential difference (p.d.) varies with time.



Which of the following is correct?

☒ **A** The frequency is 4.5 Hz.

☒ **B** The peak value is 4.0 V.

☒ **C** The period is 0.20 s.

☒ **D** The root mean square value of p.d. is 1.0 V.

(Total for Question 1 = 1 mark)

2 The π^- particle has a mass of 140 MeV / c^2.

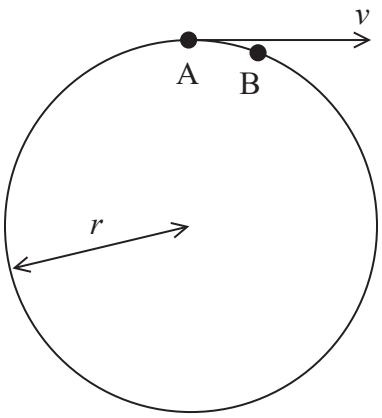
Which row of the table is correct for the antiparticle of a π^-?

	Particle classification	Mass / MeV/c^2
☒ **A**	Baryon	+140
☒ **B**	Baryon	−140
☒ **C**	Meson	+140
☒ **D**	Meson	−140

(Total for Question 2 = 1 mark)

11 The International Space Station (ISS) orbits the Earth with a constant speed v. The orbit is circular and of radius r.

(a) The diagram represents two positions, A and B, of ISS during its orbit.



Draw a labelled vector diagram, in the space below, of the velocities at the two positions that shows the acceleration is directed towards the centre of the orbit.

(2)

(b) (i) The ISS completes one orbit in 92 minutes.

Calculate the centripetal acceleration of the ISS.

$r = 6800\,\text{km}$

(3)

Centripetal acceleration = ...

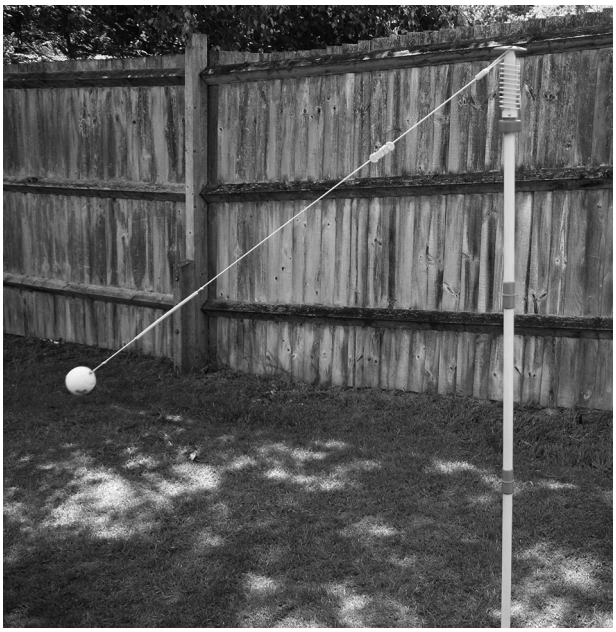
(ii) Astronauts in the ISS are often described as being "weightless".

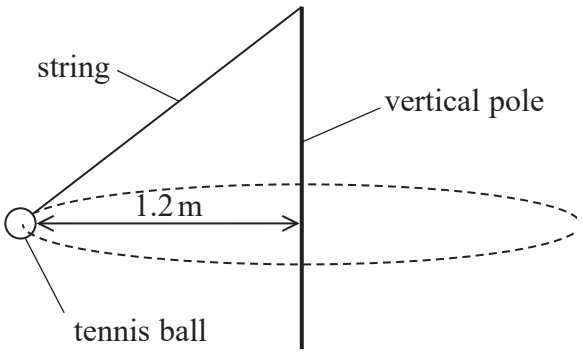
Discuss whether the astronauts are "weightless" when they are orbiting the Earth in the ISS.

(4)

(Total for Question 11 = 9 marks)

13 A 'tennis trainer' consists of a tennis ball suspended by a string from the top of a vertical pole. When the ball is hit it travels in a horizontal circle around the pole, as shown in both the photograph and the diagram.





The radius of the path of the ball is 1.2 m and the speed of the ball is 3.8 m s^{-1}.

Deduce whether these values are consistent with the angle between the string and the vertical pole shown in the photograph.

(Total for Question 13 = 5 marks)

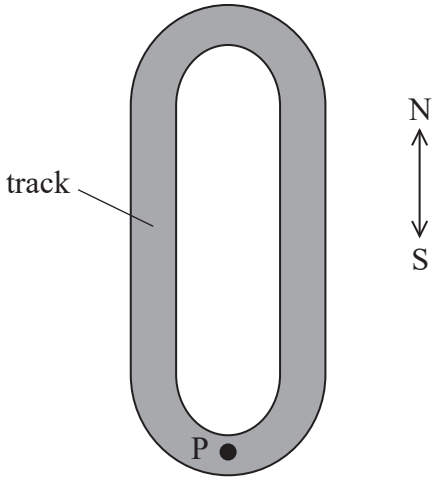
4 Muons created in the upper atmosphere can travel towards the Earth's surface at speeds close to the speed of light. Changes to the mass and average lifetime of the muons can then be observed.

Which row of the table describes these changes when muons travel at speeds close to the speed of light?

		Mass	Average lifetime
☒	**A**	increases	increases
☒	**B**	increases	decreases
☒	**C**	decreases	increases
☒	**D**	decreases	decreases

(Total for Question 4 = 1 mark)

5 The plan view of a model racing car track is shown. Friction acts between a model racing car and the track. A car is moving round the track with a constant speed and reaches point P. Arrows indicating directions North and South are also shown.



The car then slides off the track at P.

Which of the following is the reason why the car slides off the track?

☒ **A** The centripetal force is acting in the N direction.

☒ **B** The centripetal force is acting in the S direction.

☒ **C** The frictional force is equal to the centripetal force.

☒ **D** The frictional force is not large enough.

(Total for Question 5 = 1 mark)