Question 4

The magnitude of the acceleration due to gravity at Earth's surface is g.

Planet Y has twice the mass and half the radius of Earth. Both planets are modelled as uniform spheres.

Which one of the following best gives the magnitude of the acceleration due to gravity on the surface of Planet Y?

A. $\frac{1}{2}g$

B. $1\,g$

C. $4\,g$

D. $8\,g$

Question 4 (5 marks)

Assume that a journey from approximately 2 Earth radii ($2R_E$) down to the centre of Earth is possible. The radius of Earth (R_E) is 6.37×10^6 m. Assume that Earth is a sphere of constant density.

A graph of gravitational field strength versus distance from the centre of Earth is shown in Figure 4.

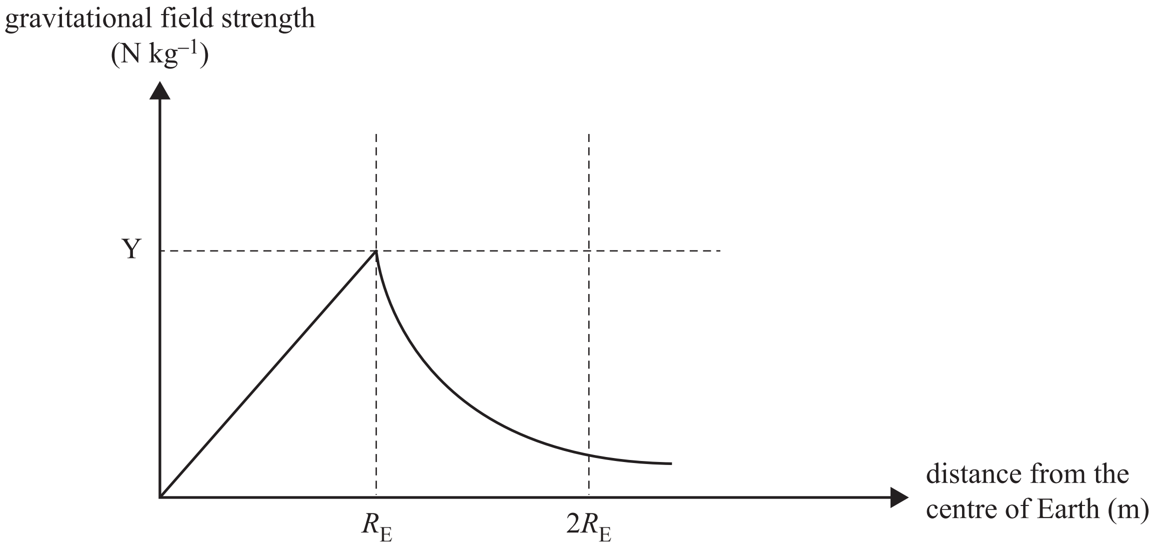

Figure 4

a. What is the numerical value of Y? 1 mark

N kg^{-1}

b. Explain why gravitational field strength is 0 N kg^{-1} at the centre of Earth. 2 marks

c. Calculate the increase in potential energy for a 75 kg person hypothetically moving from the centre of Earth to the surface of Earth. Show your working. 2 marks

J

Question 5 (5 marks)

Navigation in vehicles or on mobile phones uses a network of global positioning system (GPS) satellites. The GPS consists of 31 satellites that orbit Earth.

In December 2018, one satellite of mass 2270 kg, from the GPS Block IIIA series, was launched into a circular orbit at an altitude of 20 000 km above Earth's surface.

a. Identify the type(s) of force(s) acting on the satellite and the direction(s) in which the force(s) must act to keep the satellite orbiting Earth. 2 marks

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b. Calculate the period of the satellite to three significant figures. You may use data from the table below in your calculations. Show your working. 3 marks

Data

mass of satellite	2.27×10^{3} kg
mass of Earth	5.98×10^{24} kg
radius of Earth	6.37×10^{6} m
altitude of satellite above Earth's surface	2.00×10^{7} m
gravitational constant	6.67×10^{-11} N m^{2} kg^{-2}

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s

Question 8 (9 marks)

A 250 g toy car performs a loop in the apparatus shown in Figure 8.

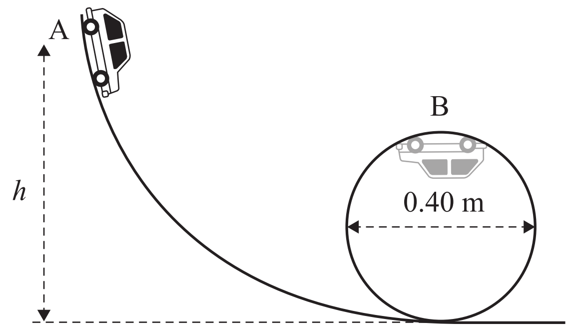

Figure 8

The car starts from rest at point A and travels along the track without any air resistance or retarding frictional forces. The radius of the car's path in the loop is 0.20 m. When the car reaches point B it is travelling at a speed of 3.0 m s^{-1}.

a. Calculate the value of *h*. Show your working. 3 marks

m

b. Calculate the magnitude of the normal reaction force on the car by the track when it is at point B. Show your working. 3 marks

N

c. Explain why the car does not fall from the track at point B, when it is upside down. 3 marks

Question 9 (3 marks)

A proton in an accelerator detector collides head-on with a stationary alpha particle, as shown in Figure 9a and Figure 9b. After the collision, the alpha particle travels at a speed of 4.0×10^6 m s^{-1}. The proton rebounds at 6.0×10^6 m s^{-1}.

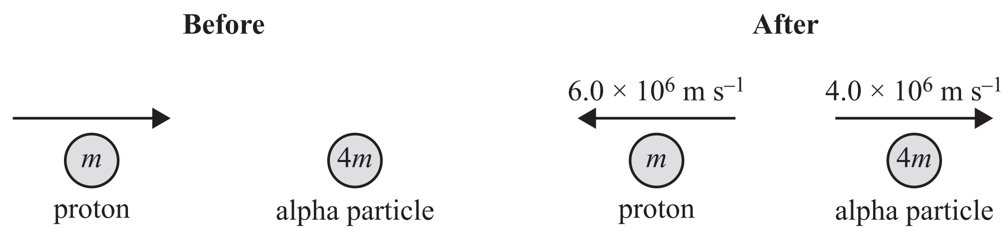

Figure 9a **Figure 9b**

Find the speed of the proton before the collision, modelling the mass of the alpha particle, $4m$, to be equal to four times the mass of the proton, m. Show your working. Ignore relativistic effects.

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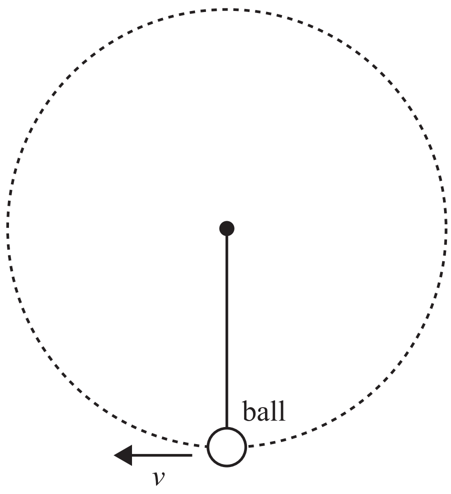
m s^{-1}

Question 8

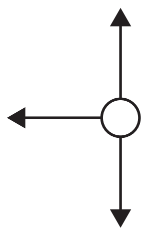
A ball is attached to the end of a string and rotated in a circle at a constant speed in a vertical plane, as shown in the diagram below.



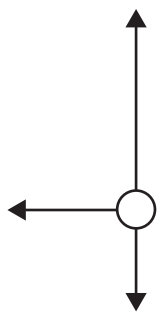
The arrows in options A. to D. below indicate the direction and the size of the forces acting on the ball.

Ignoring air resistance, which one of the following best represents the forces acting on the ball when it is at the bottom of the circular path and moving to the left?

A.



B.

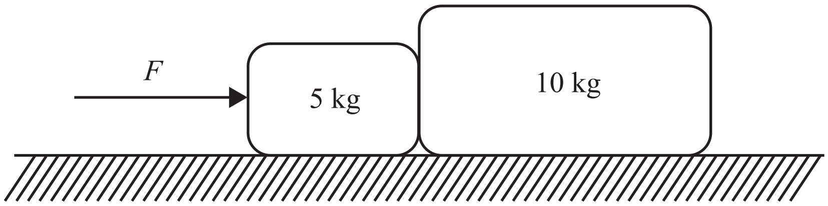


C.

D.

Use the following information to answer Questions 9 and 10.

Two blocks of mass 5 kg and 10 kg are placed in contact on a frictionless horizontal surface, as shown in the diagram below. A constant horizontal force, F, is applied to the 5 kg block.



Question 9

Which one of the following statements is correct?

A. The net force on each block is the same.

B. The acceleration experienced by the 5 kg block is twice the acceleration experienced by the 10 kg block.

C. The magnitude of the net force on the 5 kg block is half the magnitude of the net force on the 10 kg block.

D. The magnitude of the net force on the 5 kg block is twice the magnitude of the net force on the 10 kg block.

Question 10

If the force F has a magnitude of 250 N, what is the work done by the force in moving the blocks in a straight line for a distance of 20 m?

A. 5 kJ

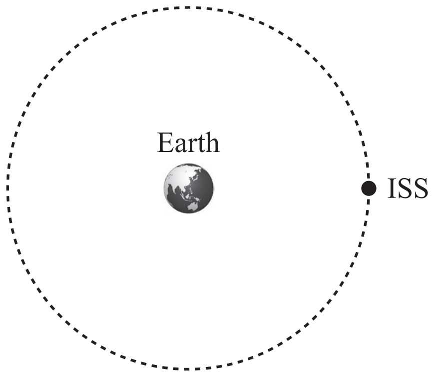
B. 25 kJ

C. 50 kJ

D. 500 kJ

Question 11

The International Space Station (ISS) is travelling around Earth in a stable circular orbit, as shown in the diagram below.



Which one of the following statements concerning the momentum and the kinetic energy of the ISS is correct?

A. Both the momentum and the kinetic energy vary along the orbital path.

B. Both the momentum and the kinetic energy are constant along the orbital path.

C. The momentum is constant, but the kinetic energy changes throughout the orbital path.

D. The momentum changes, but the kinetic energy remains constant throughout the orbital path.

Question 4 (10 marks)

The Ionospheric Connection Explorer (ICON) space weather satellite, constructed to study Earth's ionosphere, was launched in October 2019. ICON will study the link between space weather and Earth's weather at its orbital altitude of 600 km above Earth's surface. Assume that ICON's orbit is a circular orbit. Use $R_E = 6.37 \times 10^6$ m.

a. Calculate the orbital radius of the ICON satellite. 1 mark

m

b. Calculate the orbital period of the ICON satellite correct to three significant figures. Show your working. 4 marks

s

c. Explain how the ICON satellite maintains a stable circular orbit without the use of propulsion engines. 2 marks

d. Figure 3 shows the strength of Earth's gravitational field, g, as a function of orbital altitude, h, above the surface of Earth.

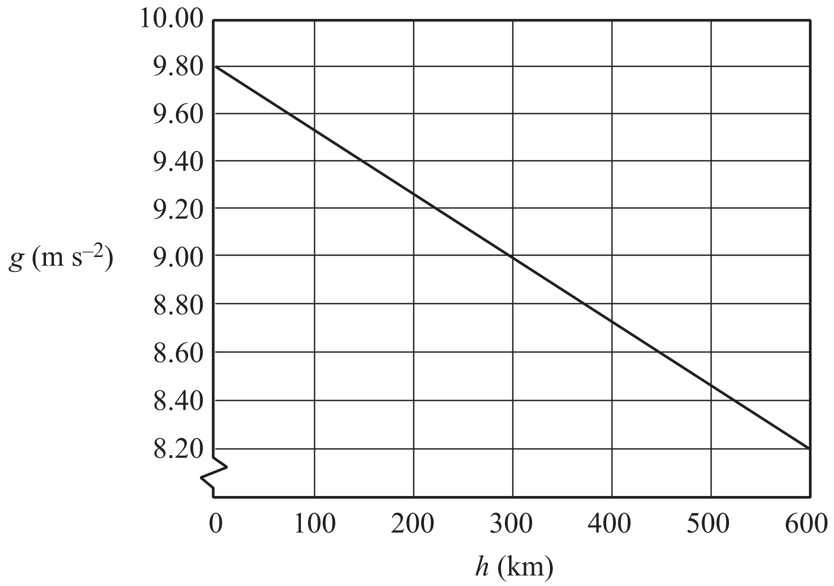


Figure 3

Determine the change in gravitational potential energy of the ICON satellite as it travels from Earth's surface to its orbital altitude of 600 km above Earth's surface. The mass of the ICON satellite is 288 kg. 3 marks

J

Question 8 (6 marks)

Figure 8 shows a small ball of mass 1.8 kg travelling in a horizontal circular path at a constant speed while suspended from the ceiling by a 0.75 m long string.

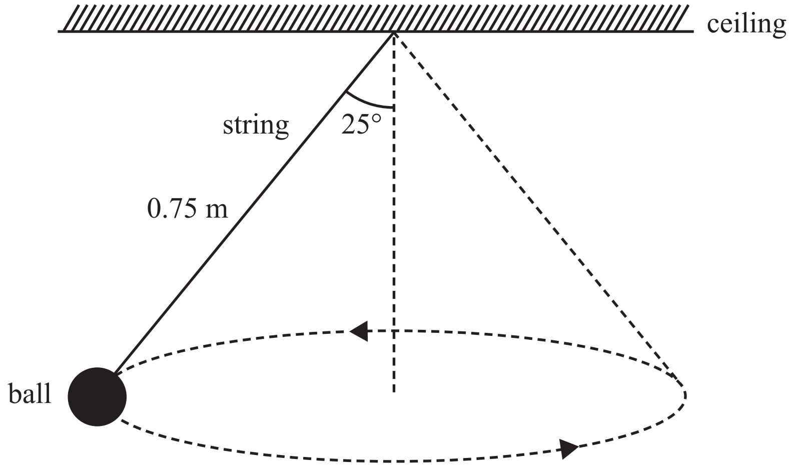


Figure 8

a. Use labelled arrows to indicate on Figure 8 the two physical forces acting on the ball. 2 marks

b. Calculate the speed of the ball. Show your working. 4 marks

m s^{-1}

Question 9 (5 marks)

An ideal spring is compressed by 0.15 m. A ball of mass 0.20 kg is placed in contact with the compressed spring. The spring is then released, causing the ball to move horizontally, with a velocity of v, across a smooth surface, as shown in Figure 9.

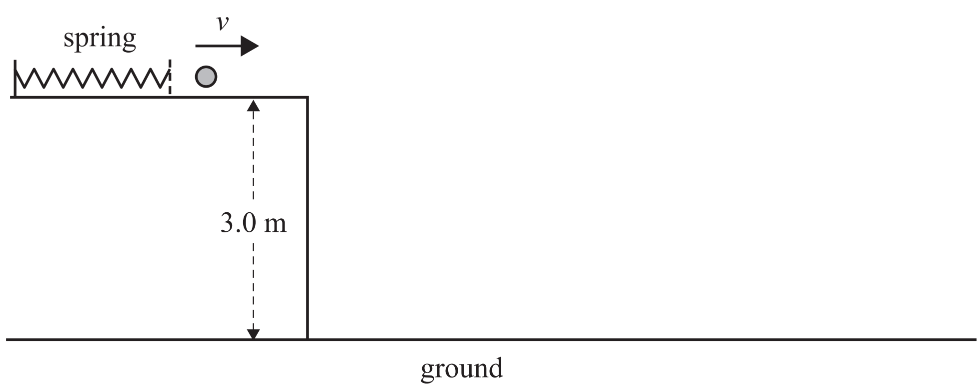


Figure 9

a. If the spring constant is 1250 N m^{-1}, show that the magnitude of the initial velocity, v, of the ball is 12 m s^{-1}, correct to two significant figures. Show your working. 2 marks

b. Calculate the speed of the ball after it has fallen a vertical distance of 2.5 m. Show your working. 3 marks

m s^{-1}

Question 10 (12 marks)

Jacinda designs a computer simulation program as part of her practical investigation into the physics of vehicle collisions. She simulates colliding a car of mass 1200 kg, moving at 10 m s^{-1}, into a stationary van of mass 2200 kg. After the collision, the van moves to the right at 6.5 m s^{-1}. This situation is shown in Figure 10.

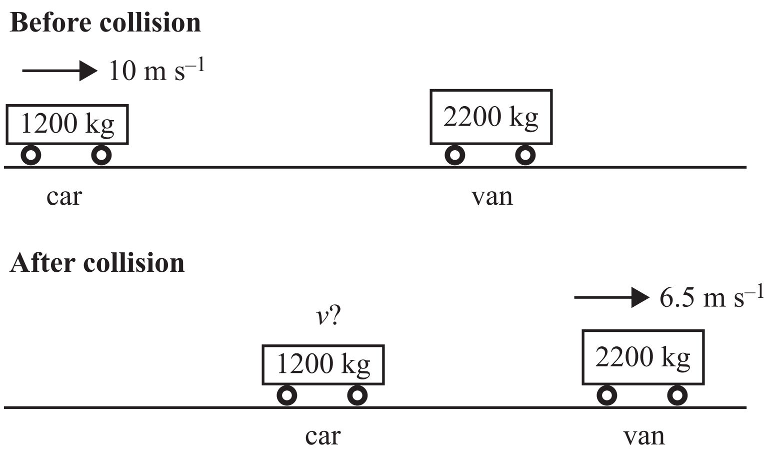


Figure 10

a. Calculate the speed of the car after the collision and indicate the direction it would be travelling in. Show your working. 4 marks

m s^{-1}

b. Explain, using appropriate physics, why this collision represents an example of either an elastic or an inelastic collision. 3 marks

c. The collision between the car and the van takes 40 ms.

i. Calculate the magnitude and indicate the direction of the average force on the van by the car. 3 marks

kN

ii. Calculate the magnitude and indicate the direction of the average force on the car by the van. 2 marks

kN