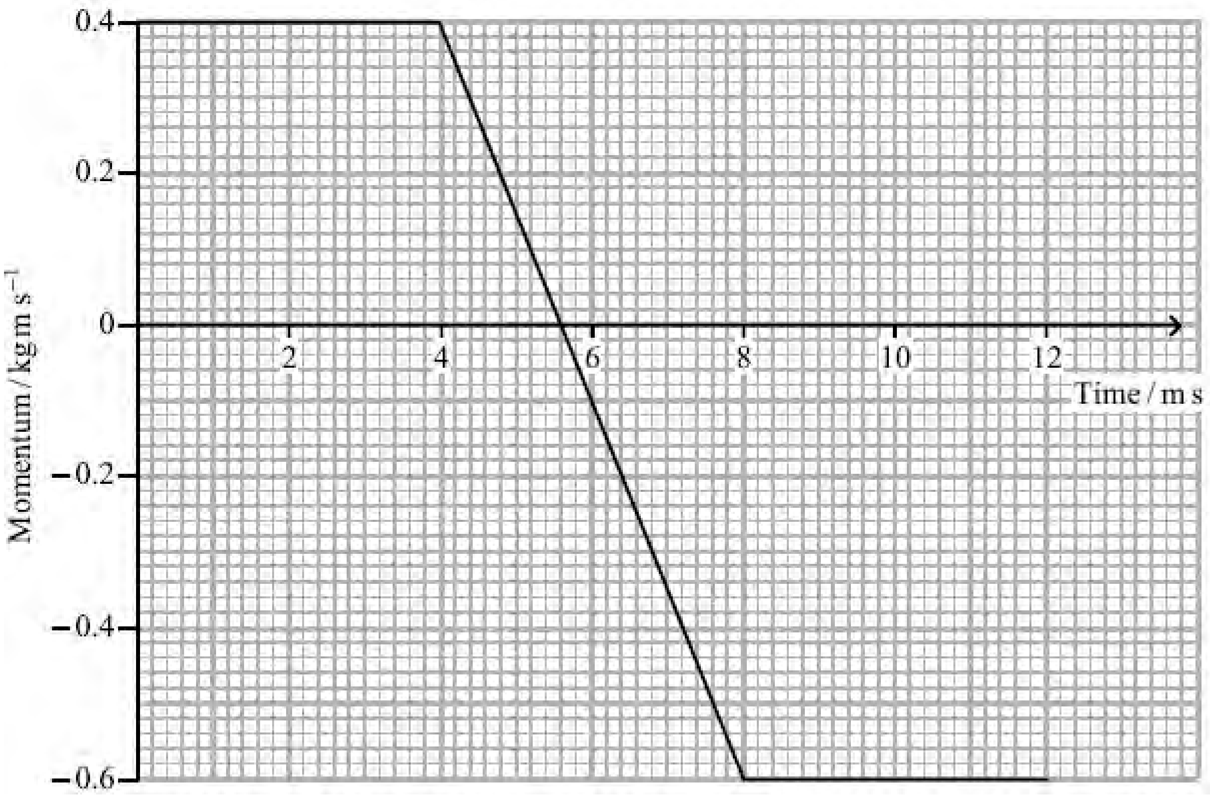
1. A tennis ball is travelling horizontally with a momentum of 0.4 kg m s^{-1} just before it is hit with a tennis racket. It rebounds horizontally from the tennis racket with a momentum of –0.6 kg m s^{-1}. The graph shows the variation in the momentum of the ball during this process.



The force exerted by the tennis ball on the racket is

A 12 N

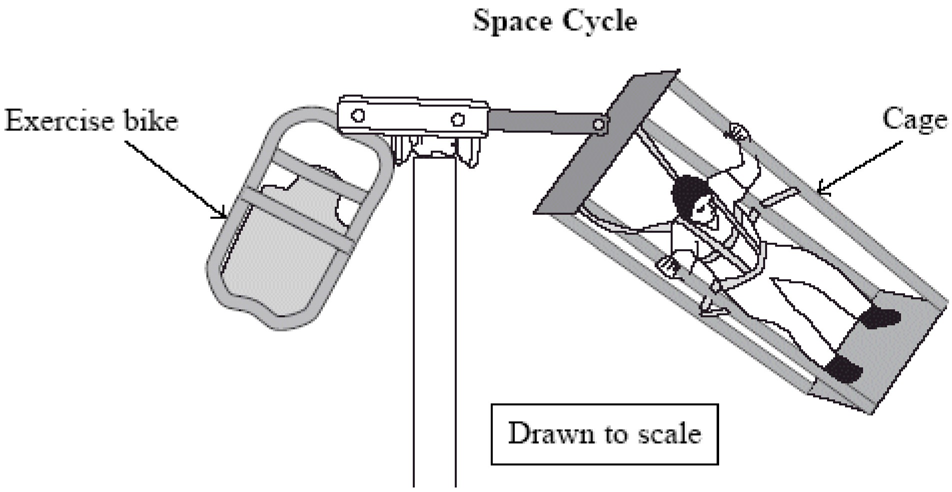
B 100 N

C 250 N

D 1000 N

(Total 1 mark)

2. Astronauts can be weakened by the long-term effects of microgravity. To keep in shape it has been suggested that they can do some exercise using a Space Cycle: a horizontal beam from which an exercise bike and a cage are suspended. One astronaut sits on the exercise bike and pedals, which causes the whole Space Cycle to rotate around a pole. Another astronaut standing in the cage experiences artificial gravity. When rotated at 20 revolutions per minute, this is of similar strength to the gravitational field on Earth.



(a) Calculate the angular velocity, in rad s^{-1}, corresponding to 20 revolutions per minute.

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Angular velocity = ...

(2)

(b) Use the diagram to estimate the radius of the path followed by the cage's platform and hence calculate the platform's acceleration.

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Acceleration = ...

(3)
(Total 5 marks)

3. How tiny bacteria move is of interest in nanotechnology. Mycobacteria move by ejecting slime from nozzles in their bodies.

Explain the physics principles behind this form of propulsion.

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(Total 4 marks)

4. The Hubble Space Telescope (HST) was launched in 1990 into an orbit of radius 6940 km. The satellite makes 15 complete orbits of the Earth every 24 hours and its position high above the Earth's atmosphere has allowed high quality images of extremely distant objects to be produced.

(a) (i) Show that the HST has a centripetal acceleration of about 8 m s^{-2}.

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(4)

(ii) The HST is kept in orbit by the gravitational pull of the Earth. Use your answer to (a)(i) to calculate a value for the mass of the Earth.

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Mass = ...

(3)

(b) The telescope was named in honour of Edwin Hubble who measured the red shift of light from a number of galaxies and related it to their distance from the Earth.

Explain what is meant by the term *red shift* in this context and state the inference that Hubble made from his measurements.

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(2)

(c) The song “Nine Million Bicycles” by Katie Melua includes the lines, “We are 12 billion light years from the edge, that’s a guess, no one can ever say it’s true”.

(i) Explain how the line “12 billion light years from the edge” implies an age of 12 billion years for the universe.

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(2)

(ii) Calculate the value of the Hubble constant consistent with an age of 12 billion years for the universe.

1 billion years = 3.15×10^{16} s

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Hubble constant = ...

(2)

(iii) These lyrics were famously contested by Dr Simon Singh in the Guardian newspaper. He argued that the correct age was 13.7 billion years, and disputed that scientists had guessed the age of the universe. As a result Katie performed the song with revised lyrics.

Discuss the suggestion in the song that values for the age of the universe are only guesses.

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(3)
(Total 16 marks)

5. A particle completes 6.0 revolutions in 4.0 s. The angular velocity, in rad s^{-1}, is

A 1.5

B 9.4

C 24

D 150

(Total 1 mark)

6. Which of the following is equivalent to the unit for energy?

A kg m^2 s^{-2}

B kg m s^{-2}

C N s^2 kg^{-1}

D N^2 s^2

(Total 1 mark)

7. A radium nucleus decays by emitting an alpha particle. The speed of the recoiling nucleus is small compared to the speed of the alpha particle. This is because the

A force acting on the recoiling nucleus is smaller than the force acting on the alpha particle

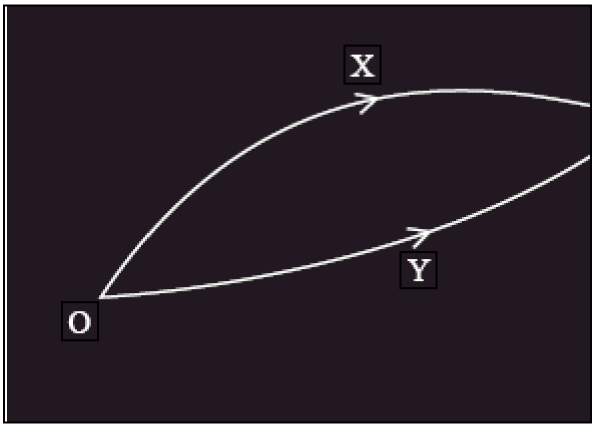
B momentum is mainly concentrated in the alpha particle

C momentum of the recoiling nucleus is smaller than the momentum of the alpha particle

D recoiling nucleus has a much larger mass than the alpha particle

(Total 1 mark)

8. A particle detector shows tracks produced by two particles X and Y that were created by the decay of a lambda particle at O.



Which of the following is a correct statement about momentum at the decay?

A The vector sum of the momenta of X and Y must equal that of the lambda particle.

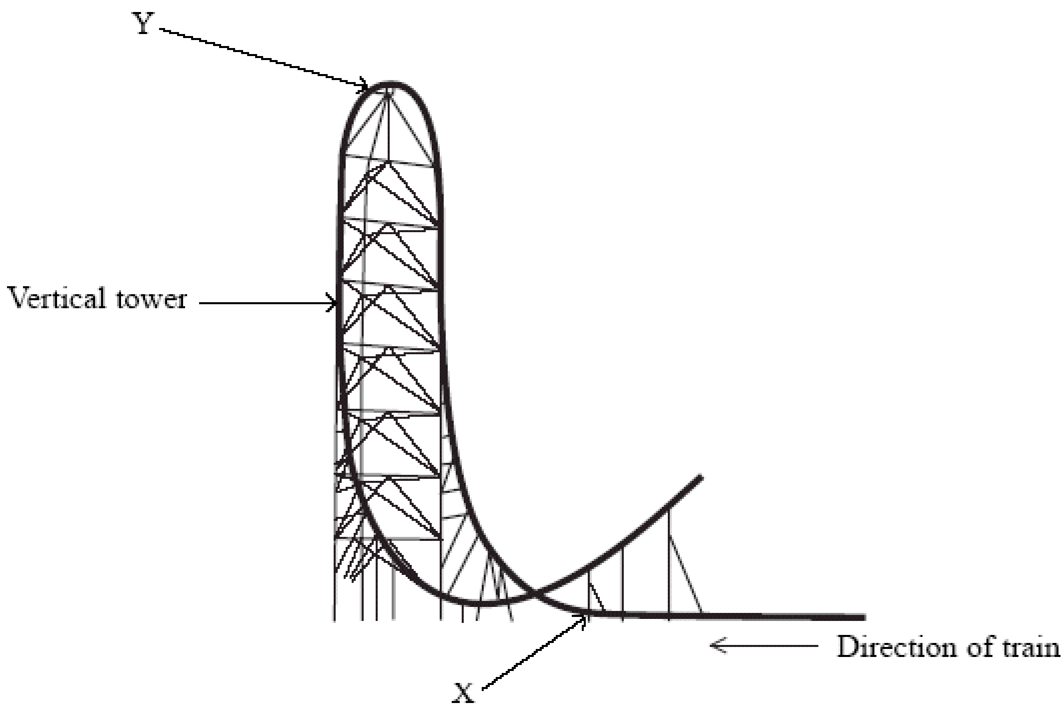
B The momentum of X is equal to that of Y.

C The total momentum of this system is zero.

D The vector sum of the momenta of X and Y must equal zero.

(Total 1 mark)

9. Kingda Ka was the highest roller coaster in the world in 2007. A train is initially propelled along a horizontal track by a hydraulic system. It reaches a speed of 57 m s^{-1} from rest in 3.5 s. It then climbs a vertical tower before falling back towards the ground.



(a) Calculate the average force used to accelerate a fully loaded train along the horizontal track.

Total mass of fully loaded train = 12 000 kg

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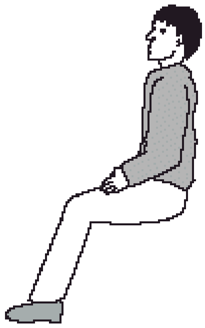
Force = ...

(2)

(b) Point X is just before the train leaves the horizontal track and moves into the first bend. Complete the free-body diagram below to show the two forces acting on a rider in the train at this point.



(3)

(c) The mass of the rider is m and g is the acceleration of free fall. Just after point X, the reaction force of the train on the rider is 4mg and can be assumed to be vertical. This is referred to as a g-force of 4*g*. Show that the radius of curvature of the track at this point is about 100 m.

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(3)

(d) Show that the speed of the train as it reaches the top of the vertical tower is about 20 m s^{-1}. Assume that resistance forces are negligible.

The height of the vertical tower is 139 m.

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(2)

(e) Riders will feel momentarily weightless if the vertical reaction force becomes zero. The track is designed so that this happens at point Y.

Calculate the radius of the track at point Y

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Radius = ...

(2)
(Total 12 marks)

10. Pion radiotherapy is a new form of cancer treatment that has been extensively investigated for tumours of the brain. Pions are short lived sub-atomic particles and belong to a group called mesons.

(a) The following table lists some quarks and their charge.

Quark	Charge / *e*
Up (u)	$+\frac{2}{3}$
Down (d)	$-\frac{1}{3}$
Strange (s)	$-\frac{1}{3}$
Charm (c)	$+\frac{2}{3}$

On the list below circle the combination which could correspond to a π^+ pion.

uud $\qquad \overline{ddd} \qquad u\bar{d} \qquad s\bar{c}$

(1)

(b) The mass of a pion is 0.14 GeV/c^2. Calculate the mass of a pion in kg.

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Mass = ... kg

(3)

(c) Pions can be produced by accelerating protons using a cyclotron. Briefly explain the role of electric and magnetic fields within a cyclotron.

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(5)

(d) When pions are used to treat brain tumours they are slowed by the tissue in the brain and cause little damage. When a pion is moving very slowly it may be absorbed by the nucleus of an atom. The atom nucleus then becomes unstable and breaks up into several fragments.

Explain why these fragments shoot out in all directions.

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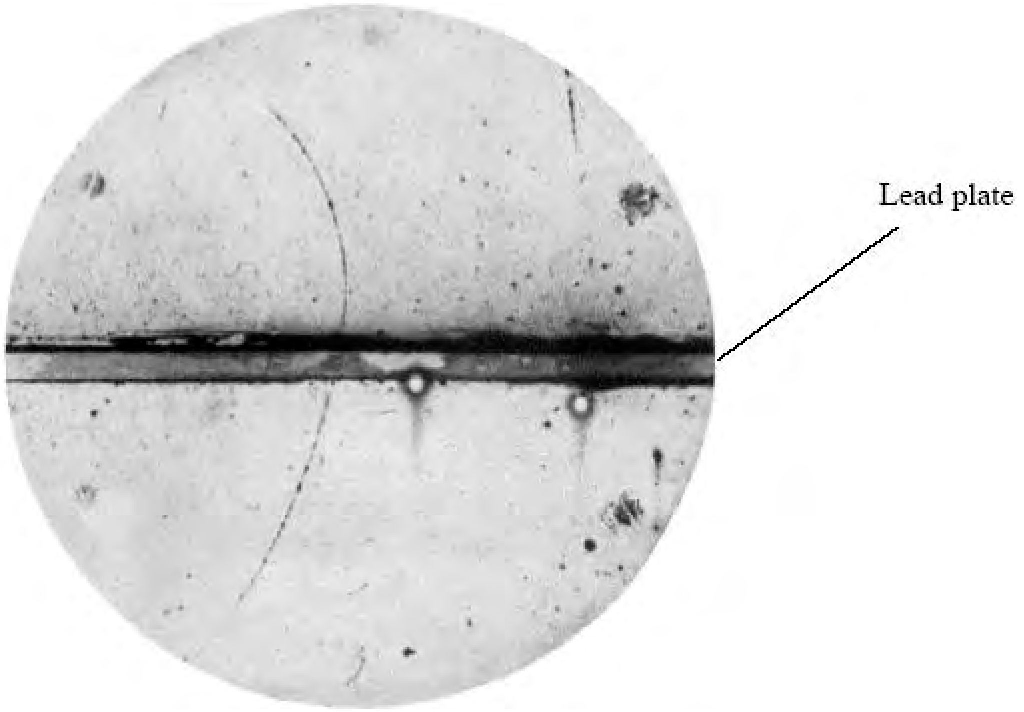
(3)
(Total 12 marks)

11. The photograph shows the track of a positively charged particle either side of a lead plate.



The particle was deflected by a magnetic field of magnetic flux density 1.5 T. The field is perpendicular to the plane of the photograph.

(a) (i) Estimate the actual radius of the track above the lead plate.

The lead plate is 6 mm thick.

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Radius = ...

(3)

(ii) Calculate the momentum of this particle above the lead plate.
Particle charge = 1.6×10^{-19} C

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....

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....

Momentum = ...

(2)

(b) Explain whether this particle was moving up or down through the lead plate.

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(3)

(c) On the list below circle the correct direction of the magnetic field.

Into the page   from left to right   down the page   out of the page   up the page

(1)

(d) This particle was identified as a positron.

(i) Calculate the speed of the positron while it is moving above the lead plate.

....

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....

Speed = ...

(2)

(ii) Comment on your answer.

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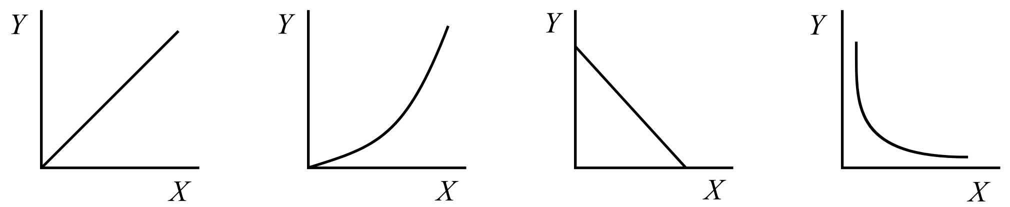
(2)

(Total 13 marks)

12. The following are four possible graphs of a quantity *Y* plotted against another quantity *X*.



A   **B**   **C**   **D**

Which graph **best** represents *Y* when it is the kinetic energy of an electron and *X* is its momentum?

(Total 1 mark)

13. Figure 1 shows the London Eye, a tourist attraction in the form of a very large wheel. Passengers ride in capsules, describing a vertical circle at constant speed. Figure 2 is a free-body force diagram showing the forces acting on a passenger in one of the capsules at point X of the circle.

Figure 1

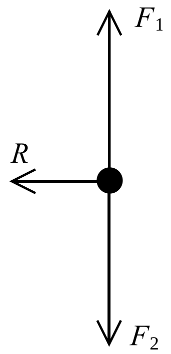


Figure 2

A teacher asks the class why the forces F_1 and F_2 are equal and opposite. A student suggests that this is because of Newton's third law.

(a) State **two** reasons why the forces F_1 and F_2 cannot be a Newton's third law pair.

Reason 1 ....

....

Reason 2 ....

....

(2)

(b) Explain why the forces F_1 and F_2 must be equal and opposite.

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(2)

(c) State what causes the force *R*.

....

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(1)
(Total 5 marks)

14. (a) State the principle of conservation of linear momentum.

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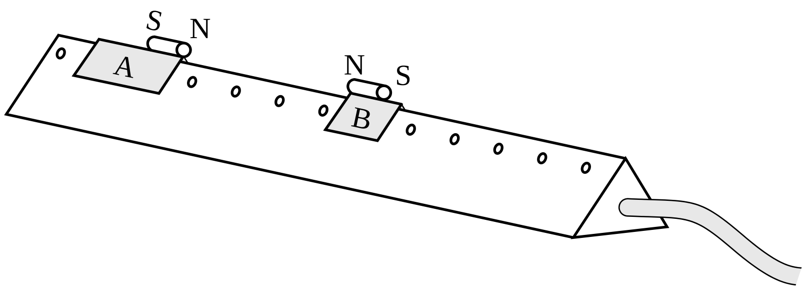
(2)

(b) The diagram shows two gliders on an air track. The magnets on the top of the gliders repel each other. The mass of glider A is 300 g and that of glider B is 100 g.



Glider A is given a push to start it moving towards glider B which is initially at rest.

Describe how you could determine the velocity of A before the gliders interact and the velocities of both A and B after the interaction. You may add to the diagram to show any additional apparatus required.

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(6)

(c) A student obtains the following velocities:

velocity of A before interaction = 5.2 cm s^{-1}
velocity of A after interaction = 2.7 cm s^{-1}
velocity of B after interaction = 7.5 cm s^{-1}

Show if these results confirm that momentum is conserved in the interaction.

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(2)
(Total 10 marks)

15. A do-it-yourself company is advertising a wind turbine that they state can deliver a power of 1 kW.

Their specification provides the following data:

- area swept out by the blades in one revolution = 2.4 m^2
- power output = 1 kW at a wind speed of 12.5 m s^{-1}
- typical operating speed of blades = 600 revolutions per minute

(a) (i) Show that the length of each blade is approximately 0.9 m.

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(1)

(ii) Show that the angular velocity of the blades at the typical operating speed is approximately 63 rad s^{-1}.

....

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(1)

(iii) Calculate the speed at which the tips of the blades will then be travelling.

Speed = ...

(1)

(b) The theoretical power available from a wind turbine is given by

$$p = ½\,\rho A v^3$$

where ρ = density of air = 1.3 kg m^{-3}
A = area swept out by blades per revolution
v = wind speed

(i) Show that when the wind speed is 12.5 m s^{-1}, the theoretical power from the advertised turbine is about 3 kW.

Power = ...

(2)

(ii) Suggest two reasons why the actual power is less than the theoretical power.

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....

(2)

(c) The manufacturer has to ensure that when the turbine is attached to a chimney stack, the force exerted on the chimney does not cause it to collapse. The turbine is designed to cut out at a wind speed of 14 m s^{-1}.

(i) Calculate the mass of air hitting the blades each second when the wind speed is 14 m s^{-1}.

Mass of air = ...

(2)

(ii) Hence calculate the maximum force that the wind could exert on the blades.

Maximum force ....

(2)

(d) The average wind speed in the UK is 5.8 m s^{-1}, which results in an actual average power output of 100W. Discuss whether it would be better for the environment to replace some filament light bulbs with low energy bulbs than to use this turbine.
Assume each filament light bulb is rated at 100W and each low energy bulb is rated at 11 W.

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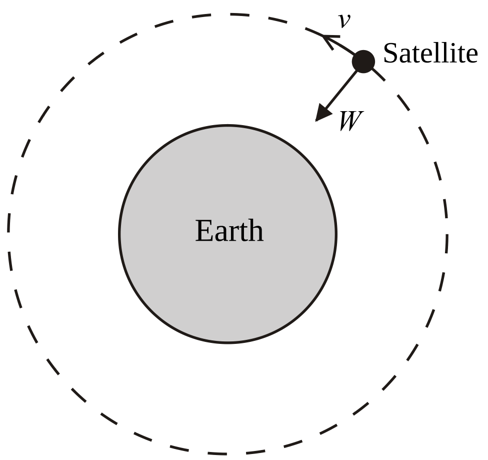
(5)
(Total 16 marks)

16. (a) A satellite is moving at a constant speed *v* in a circular orbit around the Earth. The only force acting on the satellite is its weight *W*.



(i) Although an unbalanced force is acting on the satellite, its speed does not change.

Explain why.

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(ii) According to Newton's second law, the unbalanced force causes an acceleration.

Explain how the satellite can accelerate while its speed remains constant.

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(4)

(b) A satellite used in the global positioning system travels in an orbit of radius 2.7×10^4 km. At this distance from the Earth, the acceleration of the satellite i $0.56\ \text{m s}^{-2}$.

Calculate its speed.

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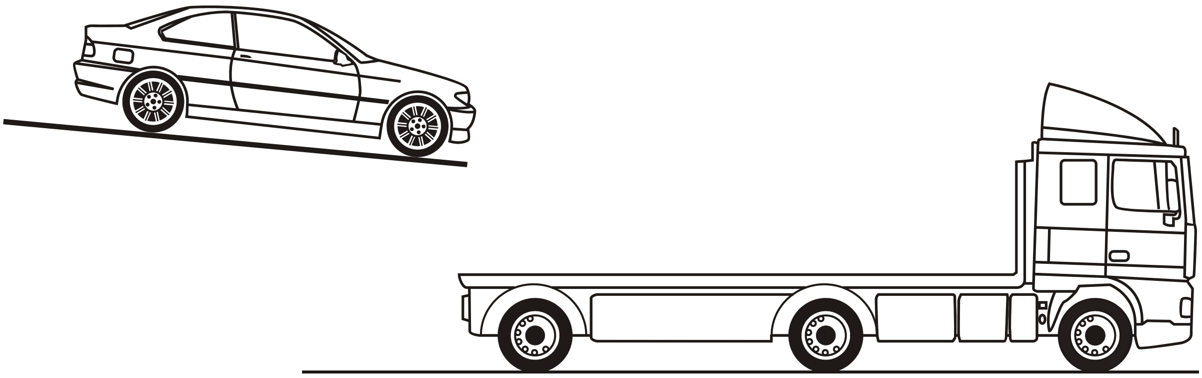
Speed = ...

(2)
(Total 6 marks)

17.



Two students are watching an action film in which a car drives down a ramp onto the back of a moving lorry. Both are moving at high speed, the car slightly faster than the lorry.

One student complains that this is impossible because the car would not be able to stop before hitting the cab of the lorry.

The car has mass 1250 kg and is moving at a speed of 28.0 m s^{-1}. The lorry has mass 3500 kg and a speed of 25.5 m s^{-1}. The length of the flat back of the lorry allows a braking distance of 5.0 m.

By considering both momentum and energy show that the stunt is possible, provided a minimum force of about 600 N slows the car down. You should support your explanations with calculations.

Treat the situation as one in which two objects join together.

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(Total 8 marks)

18. A uranium-238 nucleus, decays to a thorium-234 nucleus according to the nuclear equation

$$^{238}_{92}\text{U} \rightarrow ^{234}_{90}\text{Th} \ + \text{particle}$$

(a) Identify the particle.

....

(1)

(b) The particle is emitted with a speed of 1.41×10^{7} m s^{-1} and a kinetic energy of 6.58×10^{-13} J. Use this data to show that the momentum of the particle at the instant it is emitted is about 9×10^{-20} kg m s^{-1}.

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(4)

(c) When a decaying uranium-238 nucleus is at rest, the thorium-234 nucleus moves with a speed of 2.4×10^5 m s^{-1} in the opposite direction to the particle.

Explain with the aid of a calculation how this is consistent with the principle of conservation of momentum.

Mass of thorium-234 nucleus = 3.89×10^{-25} kg

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(3)
(Total 8 marks)

19. (a) The Earth rotates about its axis. Show that its angular speed is approximately 7×10^{-5} rad s^{-1}.

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(2)

(b) A stone is resting on the ground at a point on the equator.

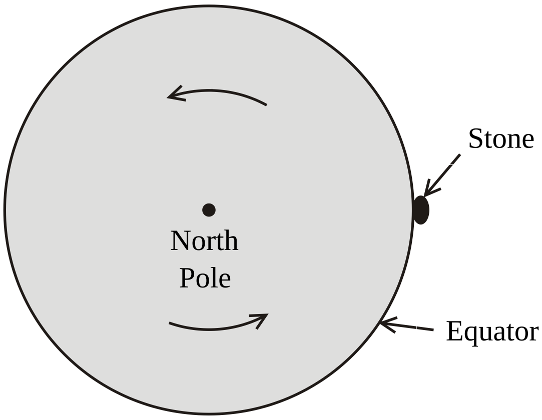

Figure 1

(i) The radius of the Earth is 6400 km. Calculate the acceleration of the stone as it follows its circular path.

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....

Acceleration = ...

(2)

(ii) Draw an arrow on Figure 1 to show the direction of the stone's acceleration.

(1)

(iii) In the space below, draw a labelled free-body force diagram for the stone when it is at the point shown in Figure 1.

(2)

(iv) With reference to your free-body force diagram, explain how the stone's acceleration is produced.

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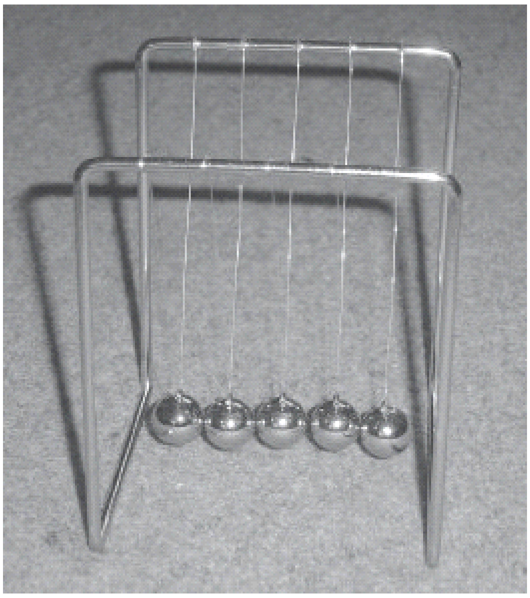
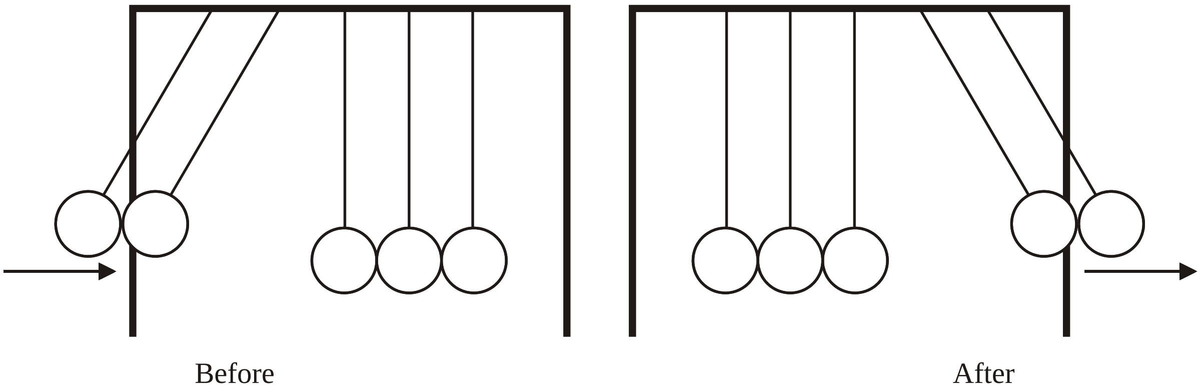
(2)
(Total 9 marks)

20. The photograph shows an arrangement known as Newton's cradle. Five steel balls are freely suspended from a frame. One or more balls on one side may be pulled back and then released so that they collide with the remaining balls.



The diagram shows what happens when two balls are released.



A student makes these measurements:

mass of each ball	= 0.024 kg
speed of the two incoming balls at impact	= 0.88 m s^{-1}

(a) Calculate the total momentum of the two moving balls before the collision.

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Total momentum = ...

(2)

(b) Show that the kinetic energy of the two moving balls before the collision is about 0.019 J.

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(2)

(c) The student notices that the number of balls moving away after the collision is always the same as the number of balls released. To understand why two balls move away after this particular collision, the student uses a spreadsheet to model the situation.
He applies the principle of conservation of momentum to find the theoretical speeds at which different numbers of balls would move away together. He also finds the kinetic energy that these balls would have.

	A	B	C	D
1	number	mass	speed after	KE after
2	of balls moving	of balls moving	collision	collision
3	away after collision	after collision	(m s^{-1})	(J)
4		(kg)		
5				
6	1	0.024	1.76	0.0372
7	2	0.048	0.88	0.0186
8	3	0.072	0.59	0.0124
9	4	0.096	0.44	0.0093
10	5	0.12	0.35	0.0074

(i) State the condition required for the total momentum of all the balls to be conserved.

....

....

(1)

(ii) Show that the value in cell C8 has been correctly calculated.

....

....

(1)

(iii) What would be a suitable formula for the calculation of cell D9?

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(1)

(iv) Explain how the spreadsheet calculations show that two balls moving away is the only likely outcome of the collision.

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(3)

(d) The two balls that moved away then swing back and collide, and the pattern is repeated. After a number of collisions, depending on the quality of the cradle, the pattern breaks down. Eventually more than two balls will be in motion, and they will not all have the same speed.

Suggest why this occurs, making reference to the spreadsheet.

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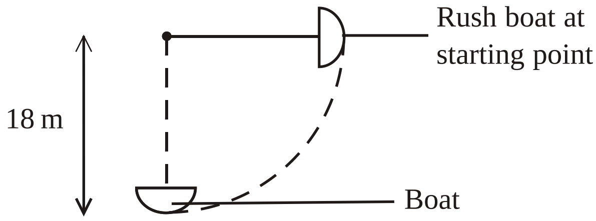
(2)
(Total 12 marks)

21. On one type of theme park ride, a boat swings freely along a circular path from successively higher starting positions. As the boat moves through the lowest point on its swing, the riders are travelling at high speeds, and feel quite big forces on them.

With some rides, such as Rush at Thorpe Park, the highest starting point is with the supporting arm horizontal as shown.



The length of the supporting arm of Rush is 18 m. The mass of a typical rider is 70 kg.

(a) Calculate the maximum "g-force" felt by a typical rider on Rush.

$$\text{"g-force"} = \frac{\text{force from seat}}{\text{weight of rider}}$$

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(5)

(b) Two students in the queue are having a discussion.

A says: "If they made a new ride twice as big the g-force at the bottom would be amazing!"

B says: "I think the g-force wouldn't be any different."

With reference to your calculation, explain which student is correct.

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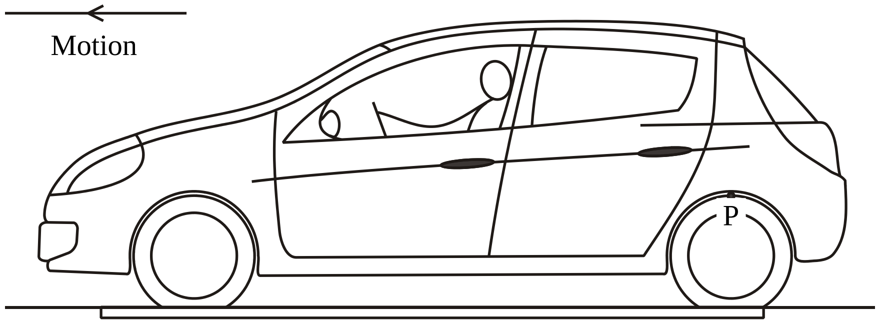
(1)
(Total 6 marks)

22. The diagram shows a car travelling at constant velocity.



(a) P is a point on the rim of one of the rear wheels. Tick the **two** boxes in the table below which describe the motion of P at the instant shown.

	To the left	Upwards	Downwards	Zero
Velocity of P				
Acceleration of P				

(2)

(b) When the tyres are correctly inflated, the effective radius of each wheel is 28 cm. Calculate the period of rotation of the wheels when the car is travelling at 21 m s^{-1}.

....

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Period = ...

(2)

(c) (i) Low tyre pressures would reduce the effective radius of the wheels. Explain how this would change the angular speed of the wheels at a given road speed.

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(1)

(ii) The reading on the car's speedometer is determined by the frequency of rotation of the wheels, so it is accurate only if the tyres are correctly inflated. Explain whether the speedometer would read too high or too low if the tyre pressures were too low.

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(1)
(Total 6 marks)

23. Communication satellites are often placed in geostationary orbit. The speed v of a geostationary satellite is given by the expression

$$v = \omega r$$

where r is the radius of the orbit.

(a) A student calculates that ω has the numerical value of 7.27×10^{-5}. Show how he arrives at this figure.

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State the unit of ω.

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(3)

(b) Hence, or otherwise, calculate the height of such satellites above the Earth's surface, given that the Earth has a mass of 5.98×10^{24} kg and a radius of 6.38×10^{6} m.

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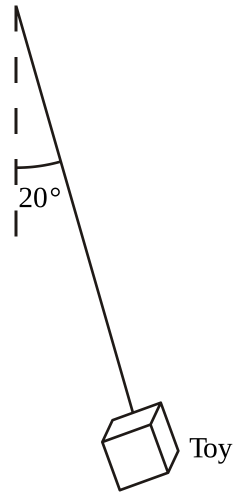
Height above Earth's surface = ...

(4)
(Total 7 marks)

24. A small fluffy toy hangs on a string in the rear window of a car. As the car travels round a bend at 30 m s^{-1} the string hangs sideways at an angle of 20° to the vertical.

(i) Mark on the diagram the forces acting on the toy.



(ii) Calculate the radius of the curve in the road.

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Radius = ...

(Total 5 marks)

25. Meteosat is a weather satellite which is in a geostationary orbit around the Earth, i.e. it stays above the same point on the Earth's surface all the time.

(a) Write down an expression for the gravitational force on this satellite, mass *m*, in an orbit of radius *r* around the Earth, mass *M*.

....

....

(1)

(b) Hence derive an expression for the gravitational field strength at a distance *r* from the centre of the Earth.

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(1)

(c) Use this, together with an expression for the centripetal acceleration, to show that the radius *r* of the geostationary orbit is given by

$$r^3 = \frac{GMT^2}{4\pi^2}$$

where *T* is the time for one orbit of the satellite.

....

....

....

....

....

(3)

(d) Calculate this radius.

Mass M of the Earth = 6.0×10^{24} kg.

....

....

....

Radius = ...

(2)

(e) The mass and speed of the satellite do not appear in the above equation. Explain whether a satellite could remain in geostationary orbit with

(i) a greater mass.

....

....

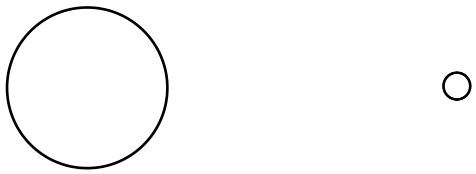
(ii) a greater speed.

....

....

(2)

(f) Explain why a satellite has to be over the equator to remain in a geostationary orbit. You may use the diagram to help your explanation.



....

....

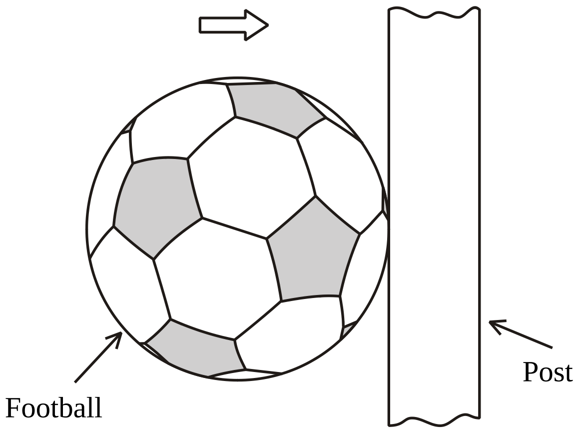
....

....

(2)

(Total 11 marks)

26. During a game of football the ball, mass 0.42 kg, is kicked towards the goal. It hits one of the posts and rebounds directly back into play. The diagram shows the ball as it is just colliding with the post. At impact its speed is 27 m s^{-1}.



(a) Calculate the ball's momentum at impact.

....

....

Momentum = ...

(2)

(b) The ball's speed at the moment it loses contact with the post is 20 m s^{-1} in the opposite direction. Calculate its momentum at this instant.

....

....

Momentum = ...

(2)

(c) (i) The ball remains in contact with the post for 0.22 s. Determine the average force exerted on the ball due to the collision.

....

....

....

Average force = ...

(3)

(ii) Show the direction of this force on the diagram.

(1)

(d) State one difference and one similarity between this force and the force that acts on the post due to the impact of the ball.

Difference: ....

....

Similarity: ....

....

(2)

(Total 10 marks)

27. An elastic collision is one in which kinetic energy is conserved.

A proton, mass 1.67×10^{-27} kg, travelling with a speed of 2.40×106 m s^{-1}, has a head-on elastic collision with a stationary helium nucleus. After the collision the helium nucleus, mass 6.65×10^{-27} kg, moves off with a speed of 9.65×10^{5} m s^{-1}.

(a) Show that the kinetic energy of the helium nucleus is approximately 3×10^{-15} J.

....

....

....

....

(2)

(b) (i) How much kinetic energy is lost by the proton?

....

(1)

(ii) Hence determine the speed of the proton after the collision.

....

....

....

....

....

....

Speed of proton = ...

(3)

(c) Name a quantity, other than kinetic energy, that is conserved in this collision.

....

(1)
(Total 7 marks)

28. Alex Coomber won a bronze medal in the women's bobsled at the 2002 Winter Olympics. This involved hurtling down an icy track on her sled at speeds of up to 35 m s^{-1}.

During one section of the run, her speed remained constant at 35 m s^{-1} as she slid in a straight line down a slope of 10°. Figure 1 shows the three forces acting upon her during this time. Figure 2 is the first part of a scale drawing combining these forces.

Figure 1

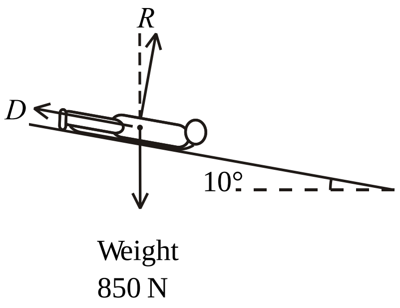
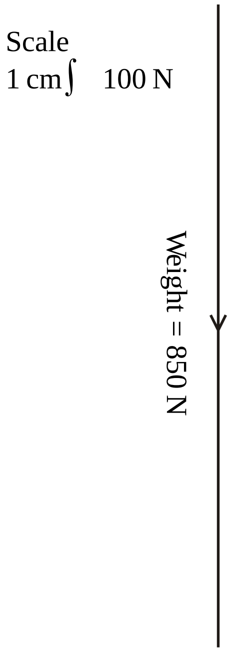


Figure 2



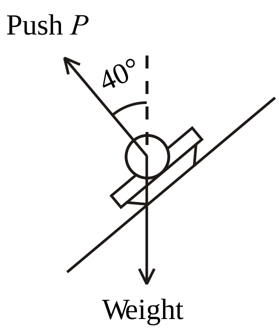
(a) Complete the scale drawing to find the size of the drag force *D*.

Drag force *D* = ...

(3)

Figure 3 shows Alex turning a corner. The banking angle is 40°. Figure 3 shows the two forces which affect her as she takes the corner at a speed of 35 m s^{-1}.

Figure 3



(b) Show that the size of *P*, the push on the sled from the ice, is about 1000 N.

....

....

....

(2)

(c) (i) Explain why there needs to be a resultant force on Alex to take her round the corner.

....

....

....

(2)

(ii) State what provides this force.

....

....

....

(2)

(d) Calculate the radius of the corner. The combined mass of Alex and the sled is 87 kg.

....

....

....

....

....

Radius = ...

(3)
(Total 12 marks)

29. (a) State Newton's second law of motion in terms of momentum.

....

....

....

....

(2)

(b) A wind blows steadily against a tree. The area of the tree perpendicular to the direction of the wind is 10 m^2 and the velocity of the wind is 20 m s^{-1}.

(i) Show that the mass of air hitting the tree each second is about 250 kg. (Density of air is 1.23 kg m^{-3}.)

....

....

....

....

(2)

(ii) Calculate the momentum of this mass of air when it is moving at 20 m s^{-1}.

....

....

Momentum = ……………………………………

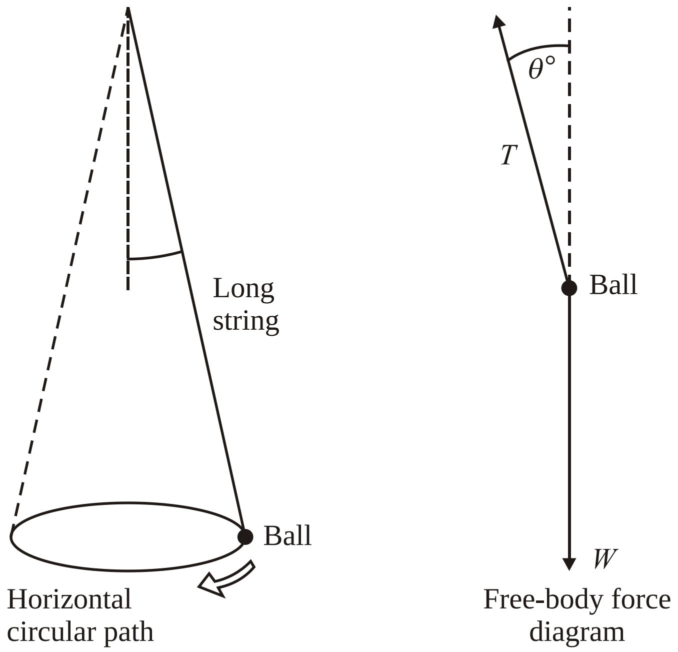
(iii) Assuming that all the air is stopped by the tree, state the magnitude of the force exerted on the tree by the wind.

....

Force = ……………………………………

(2)
(Total 6 marks)

30. A ball attached to the end of a long string is made to rotate in a horizontal circular path at a constant speed. The forces acting on the ball are its weight, *W,* and the tension, *T*, in the string.



With reference to the free-body force diagram, explain how it is possible for the ball to move with constant speed and yet still be accelerating.

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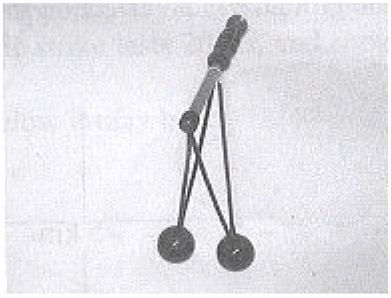
(Total 4 marks)

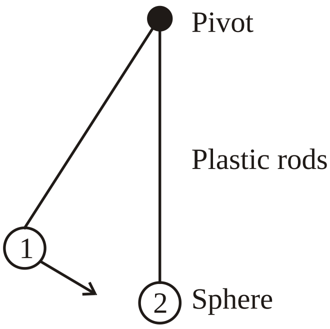
31. The picture shows a toy with two plastic spheres, each suspended by plastic rods. Each sphere is able to swing freely in a vertical circle.



A student decides to carry out an experiment with the toy to investigate momentum. He allows one sphere to strike the other, and measures their speeds just before and just after the collision.

The table shows his data for one collision.

mass of sphere 1	54.0 g
mass of sphere 2	29.0 g
speed of sphere 1 before collision	2.57 m s^{-1}
speed of sphere 2 before collision	0
speed of sphere 2 after collision	2.12 m s^{-1}



Show that the speed of sphere 1 just after the collision is about 1.4 m s^{-1}. Assume that the mass of each rod is negligible.

....

....

....

....

....

(3)

Determine whether this is an elastic collision or an inelastic collision.

....

....

....

....

....

(3)

In another experiment the student uses the toy to investigate motion in a vertical circle. He times sphere 2 (mass 29 g) as it swings around a complete vertical circle of radius 17 cm. This takes 0.37 s.

Calculate the average speed of the sphere.

....

....

Speed = ...

(2)

Assuming that the sphere travels at this speed throughout its circular path,

(i) calculate the centripetal force acting on it while it is in motion

....

....

....

Centripetal force = ...

(2)

(ii) calculate the net force exerted by the rods on the sphere when it is at the top of the circle.

....

....

....

Tension = ...

(2)

(Total 12 marks)

32. Most smoke detectors contain an isotope of Americium (241Am), the nuclei of which decay by emitting an alpha particle. When a nucleus of Americium emits an alpha particle the principle of conservation of momentum and the principle of conservation of energy are obeyed.

Show that the ratio $\frac{\text{kinetic energy of alpha particle}}{\text{kinetic energy of resulting nucleus}}$ is about 60 and briefly discuss the origin of this energy.

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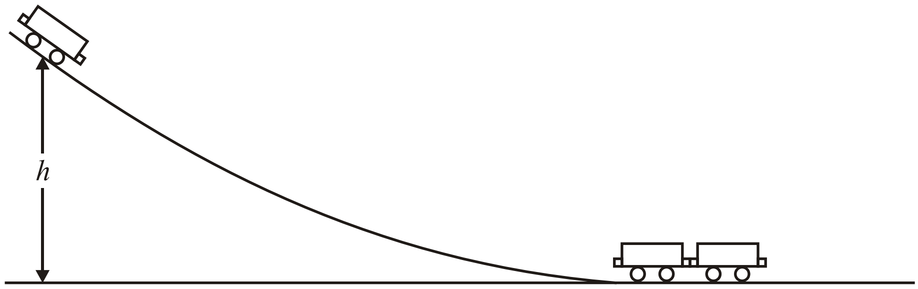
(Total 6 marks)

33. (a) A toy truck of mass 80 g is released from a height *h* and rolls down a slope as shown below.



What would the height *h* have to be for the truck to reach a speed of 4.0 m s^{-1} at the bottom of the slope? You may assume that any friction at its axles is negligible.

....

....

....

....

....

....

Height = ...

(3)

(b) On reaching the bottom, it joins magnetically to two stationary trucks, identical to the first, and the trucks all move off together.

(i) State the law of conservation of linear momentum.

....

....

....

....

....

(2)

(ii) Use this law to calculate the speed of the trucks immediately after the collision.

....

....

....

....

....

Speed = ……………………………………….

(2)

(c) One of the stationary trucks has a total frictional force of 0.12 N at its axles. How much time does it take for the three trucks to stop moving if this is the only frictional force acting?

....

....

....

....

....

....

....

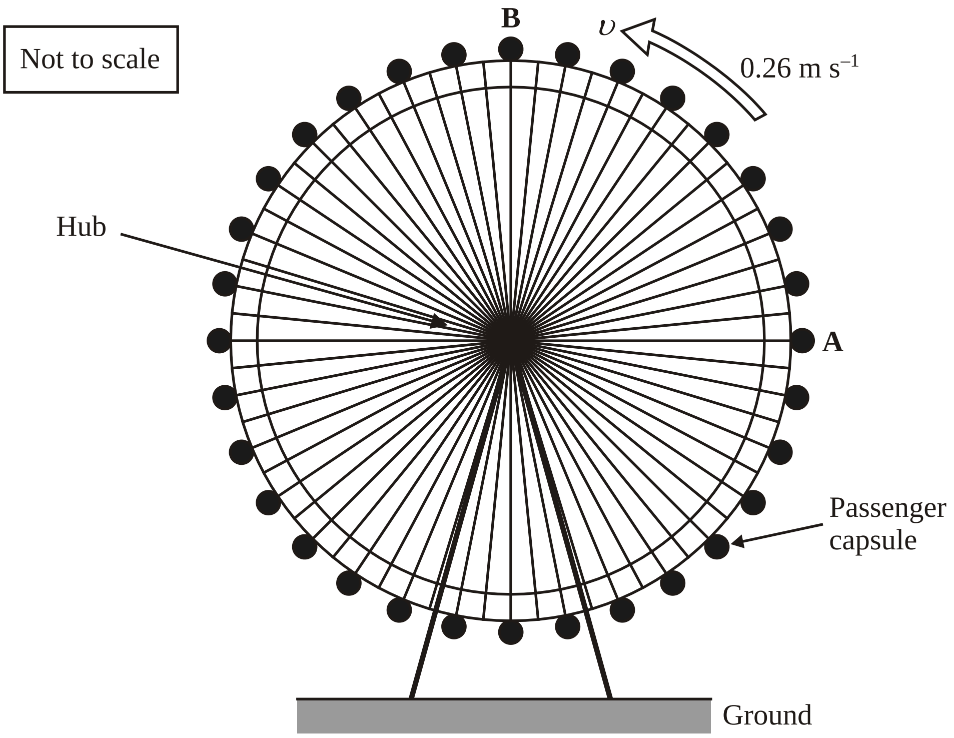
....

Time = ………………………………………

(3)
(Total 10 marks)

34. The London Eye is a tourist attraction designed to give passengers a panoramic view over London. The giant wheel completes two revolutions in one hour. Each capsule moves with a constant speed of 0.26 m s^{-1} as it follows a circular path.

Figure 1



(a) Calculate the radius of this circular path.

....

....

....

....

Radius = ...

(2)

(b) A man of mass 85 kg follows a circular path of this radius as he rides in a capsule. What is the magnitude and direction of the resultant force acting on the man?

....

....

....

....

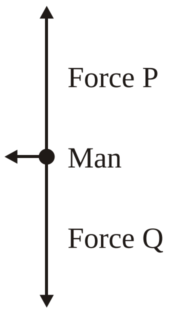
....

....

(3)

(c) Figure 2 shows the free-body force diagram for the man when the capsule is at position **A** as shown in Figure 1.

Figure 2



(i) Name forces P and Q

Force P: ....

Force Q: ....

(2)

(ii) When the man is at position A there is no resultant **vertical** force acting on him. In this position force P = force Q in magnitude. Explain why the man continues his motion in a circle.

....

....

....

(2)

(iii) Explain why force Q must be larger than force P when the capsule is at position B.

....

....

....

(1)
(Total 10 marks)

35. A class is visiting a go-karting track to study the physics involved.

To keep a go-kart moving forward at constant speed, the engine must exert a forward force. When a go-kart at constant speed goes round a bend in the track, an additional force is required.

State the direction in which this additional force acts.

....

(1)

Explain why this additional force is required.

....

....

....

....

(2)

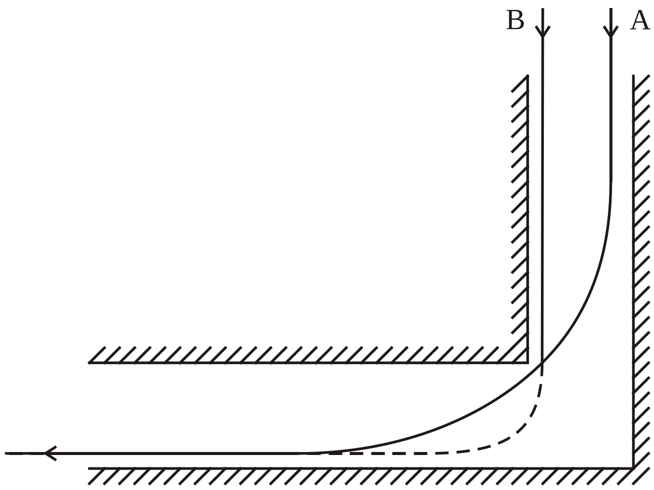
State what provides this additional force.

....

.... **(1)**

As an initial experiment, student A sits in the go-kart and his classmates attach a forcemeter to its side and drag it sideways. They find that the force needed to make it begin to slide sideways over the ground is 470 N.

At one point on the circuit the track bends through a right-angle as shown.



Student A drives his kart round this bend taking the path marked A. The radius of this circular path is 14 m. Calculate the maximum speed at which he can drive round this bend. The total mass of student A and his kart is 160 kg.

....

....

....

....

Maximum speed = ...

(3)

Student B and his kart have the same total mass as student A and his kart. Student B approaches the same corner at the same speed as student A did (the maximum speed that you calculated for student A). He intends to take the dotted path shown. However, he slides off the track.

Explain why he is not able to follow the dotted path.

....

....

....

....

....

(3)

The teacher and his kart have a mass much greater than 160 kg. He approaches the bend along the same path that student A took, at the same speed. Explain whether he would be likely to get round the corner at this same speed without sliding off the track.

....

....

....

....

(2)
(Total 12 marks)

36. (a) Explain why a body moving at constant speed in a circular path needs a resultant force acting on it.

....

....

....

....

(2)

(b) (i) A girl standing at the equator is in circular motion about the Earth's axis. Calculate the angular speed of the girl.

....

....

....

Angular speed = ...

(2)

(ii) The radius of the Earth is 6400 km. The girl has a mass of 60 kg. Calculate the resultant force on the girl necessary for this circular motion.

....

....

Force = ...

(2)

(iii) If the girl were to stand on weighing scales calibrated in newtons, what reading would they give?

....

....

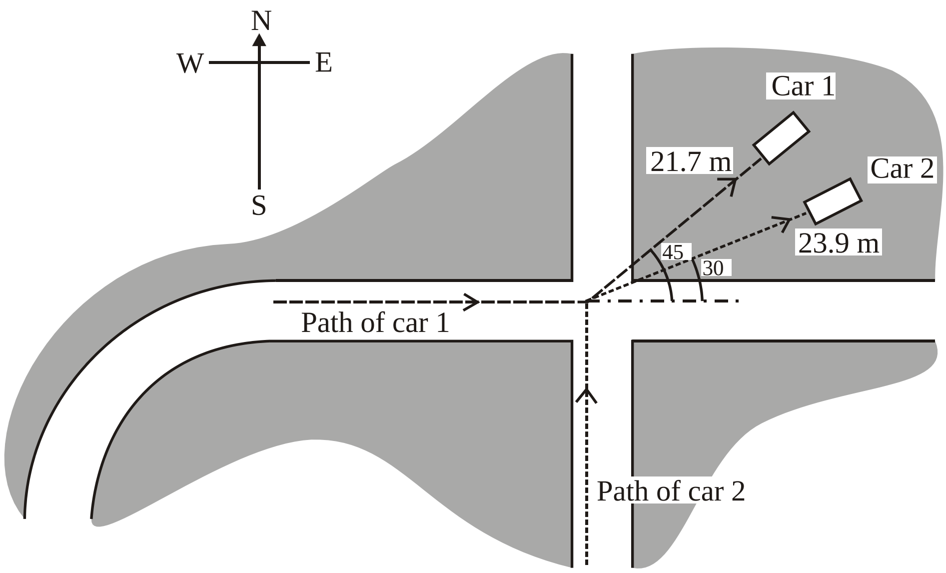
....

Scale reading = ...

(3)

(Total 9 marks)

37. The diagram is taken from the notes of an accident investigator after a collision in the countryside.



The driver of car 1 said he was driving within the speed limit and car 2 suddenly drove across the junction in front of him.

The driver of car 2 said that he obeyed the traffic sign and stopped at the junction. He looked carefully before moving slowly straight across the junction. He was suddenly struck by car 1. He thought he hadn't seen it because of the bend in the road 50 m away, and that it must have been speeding.

The investigator found the masses of both cars with their drivers and used a test car to find that the surface produced a deceleration of 3.43 m s^{-2}. The table shows some of the investigator's notes.

	Car 1	Car 2
Mass of car and driver/kg	1950	1430
Distance travelled after collision/m	21.7	23.9
Angle between path followed and main road/degrees	45.0	30.0
Speed immediately after collision/m s^{-1}	12.2	
Magnitude of momentum immediately after collision/kg m s^{-1}	23 800	

Show that the speed of car 2 immediately after the collision was about 13 m s^{-1}.

....

....

....

....

(2)

Calculate the magnitude of the momentum of car 2 immediately after the collision.

....

....

....

Momentum = ...

(2)

Next the investigator calculated the component of the momentum to the East immediately after the collision for each car.

Calculate this component of the momentum for each car.

....

....

....

....

East momentum component for car 1 = ...

East momentum component for car 2 = ...

(3)

Hence determine whether car 1 was speeding before the accident. The speed limit was 17.8 m s^{-1}.

....

....

....

....

(3)

Explain, without calculation, how the investigator could use a conservation law to deduce that car 2 was travelling across the junction at speed.

....

....

....

....

(2)
(Total 12 marks)

38. A neutron of mass 1.7×10^{-27} kg travelling at $2.96 \times 10^{7} \text{ m s}^{-1}$ collides with a stationary nucleus of nitrogen of mass 23.3×10^{-27} kg. Calculate the magnitude of the momentum of the neutron before it collides with the nucleus of nitrogen.

....

....

Momentum of neutron = ...

(2)

Given that the neutron ‘sticks’ to the original nucleus after the collision, calculate the speed of the new heavier nucleus of nitrogen.

....

....

....

....

Speed = ...

(3)

An elastic collision is one where kinetic energy is conserved. Make suitable calculations to determine whether this collision is elastic.

....

....

....

....

....

....

(3)
(Total 8 marks)

39. To make an object of mass m move at speed υ around a circular path of radius r, a resultant force must act on it. The magnitude of the resultant force is given by $m\upsilon^2/r$.

Explain why a resultant force is required, and state its direction.

....

....

....

....

(3)

When vehicles corner on a level road, the resultant force is provided by friction. For a given vehicle and road surface, the friction cannot exceed a certain maximum value. Use these facts, together with the expression for the resultant force, to explain why roads designed for high-speed travel have no sharp bends.

....

....

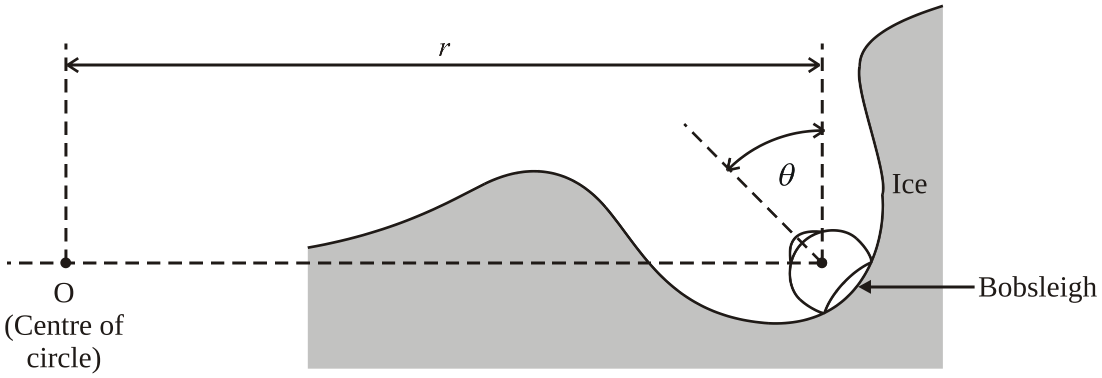
....

....

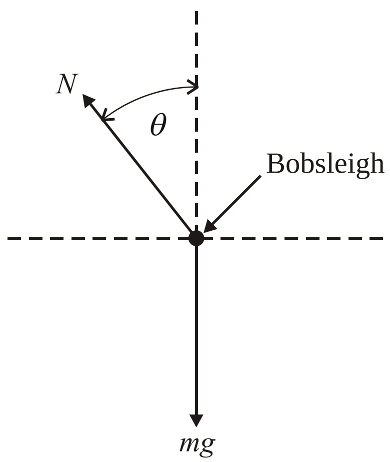
(2)

On a bobsleigh run, the bobsleigh travels along an ice channel with little friction. When cornering, it slides up the side of the channel until the required resultant force is provided.

The diagram shows a head-on view of a bobsleigh travelling at speed υ round a bend which is part of a horizontal circle centred at the point O. The bobsleigh is tilted through an angle θ.



Below is a free-body force diagram for the bobsleigh. Friction is assumed to be negligible.



The normal contact force exerted by the ice on the bobsleigh is N, and its weight is mg.

Write down an equation expressing the condition for no vertical acceleration.

....

Write down an equation applying Newton's second law horizontally.

....

Hence show that

$$\tan\theta = \frac{v^2}{rg}$$

($\tan\theta = \sin\theta / \cos\theta$)

....

....

....

....

(4)

Calculate the value of angle θ for a bobsleigh travelling at 30.0 m s^{-1} around a bend of radius 20.0 m.

....

....

θ =…...

(1)

(Total 10 marks)

40. A possible explanation for the extinction of the dinosaurs is that the Earth was struck by an asteroid. Studies are currently under way to find a way of avoiding such a collision in the future. One possibility is to change the orbit of an asteroid which is on a collision course with the Earth. This could be done by hitting it with a large mass in order to change its velocity.

Simulations of the impact of a 5.8×10^6 kg mass on the asteroid Castalia, mass 1.2×10^{12} kg, have been carried out to predict the effect. In all the simulations the two bodies join together on impact. The speed of the colliding mass was taken as 35 000 m s^{-1}, and that of Castalia as 25 000 m s^{-1}.

Discuss whether this would be an elastic or an inelastic collision.

....

....

....

....

....

(2)

If the mass strikes Castalia at 90°, sketch a momentum vector diagram labelled with the appropriate quantities. The diagram does not need to be drawn to scale.

(2)

Hence calculate the resulting change in Castalia's direction.

....

....

....

....

Change in direction = ...

(2)

Such an impact may fracture the asteroid and leave some fragments still on a collision course with the Earth. An alternative approach would be to apply a smaller steady force over a longer period, for example by using rocket engines.

State a formula for net force in terms of momentum.

....

(1)

The momentum change of Castalia at the impact is 2.0×10^{11} N s. The average thrust of a typical rocket is 7×10^{6} N, and it can burn for 130 s. Calculate the number of rockets required to produce the same change in Castalia's momentum as in the collision above.

....

....

....

....

....

Number of rockets = ...

(2)

(Total 9 marks)

41. In a washing machine clothes are placed inside a metal drum with small holes in it. When the wet clothes are spun, the drum rotates at high speed and water escapes through the holes. The drum has a radius of 0.220 m and rotates at 800 revolutions per minute.

Show that the speed of the rim of the drum is approximately 18 m s^{-1}.

....

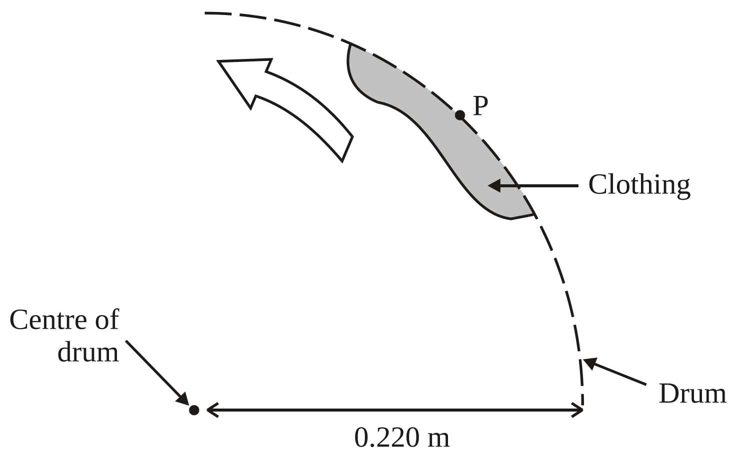
....

....

....

(3)

The diagram shows a piece of clothing in the drum which is spinning anticlockwise.



Estimate the magnitude of the acceleration of this piece of clothing.

....

....

....

Acceleration = ...

(2)

Add an arrow to the diagram to show the direction of this acceleration. Label the arrow A.

Explain what force produces this acceleration.

....

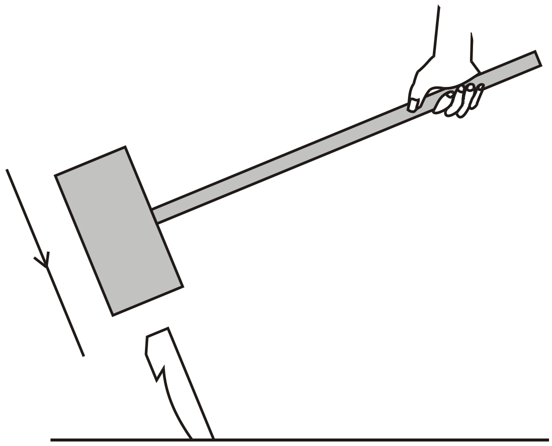
....

(2)

A drop of water becomes detached from the clothing at point P, which is next to one of the holes in the drum. Draw an arrow on the diagram to show the path which the drop of water now follows. Label this arrow B.

(1)
(Total 8 marks)

42. A wooden mallet is being used to hammer a tent peg into hard ground.



The head of the mallet is a cylinder of diameter 0.100 m and length 0.196 m. The density of the wood is 750 kg m^{-3}. Show that the mass of the head is approximately 1.2 kg.

....

....

....

....

(3)

The head strikes the tent peg as shown at a speed of 4.20 m s^{-1} and rebounds at 0.58 m s^{-1}.
Calculate the magnitude of its momentum change in the collision.

....

....

....

Momentum change = ...

(3)

The head is in contact with the peg for 0.012 s. Estimate the average force exerted on the peg by the head during this period.

....

....

Average force = ...

(2)

Give a reason why your value for the force will only be approximate.

....

....

(1)

With reference to your calculations above, discuss whether a mallet with a rubber head of the same mass would be more or less effective for hammering in tent pegs.

....

....

....

....

(2)
(Total 11 marks)

43. The momentum p of a photon of energy E is given by the expression $p = E/c$ where c is the speed of light. Show that this expression is homogeneous with respect to units.

....

....

....

....

(Total 4 marks)

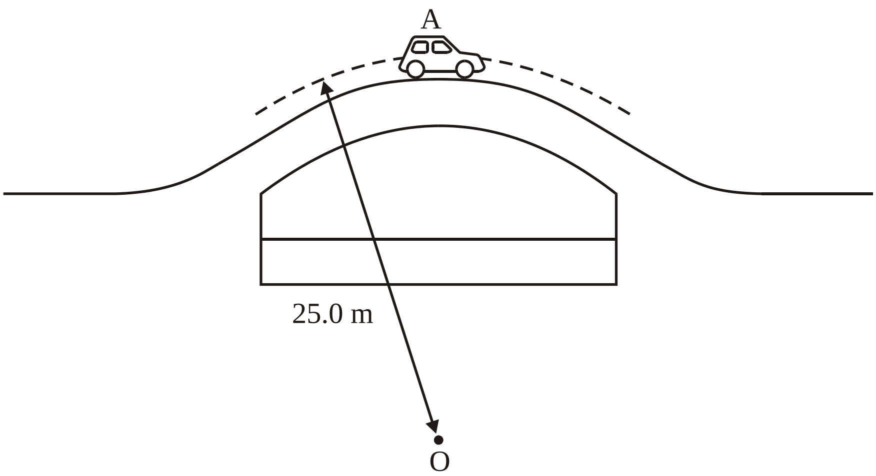
44. A body of mass m travelling at constant speed v around a circular path of radius r must have a resultant force F acting upon it. Write down a formula for the magnitude of F and state the direction in which it acts.

Formula: ....

Direction: ....

(2)

The diagram shows a car at the highest point A of a hump-backed bridge.



When the car is driven over the bridge it follows part of a vertical circle of radius 25.0 m centred at the point O below the bridge.

Below is a free-body force diagram for the car at point A.

The mass of the car is 925 kg. Calculate the normal reaction force *R*

(i) when the car is parked at rest at A,

....

R = ...

(ii) when the car is passing point A at a speed of 10.0 m s^{-1}.

....

....

....

R = ...

(4)

If the car is driven across the bridge repeatedly, at gradually increasing speeds, it is found that, above a certain critical speed, the car loses contact with the road at A, and "takes off ". Explain why this happens.

....

....

....

....

(1)

Calculate the critical speed for this particular bridge.

....

....

Critical speed = ...

(2)

An object which is in free fall is said to be "apparently weightless". Explain what this means, illustrating your answer with reference to the situation described in this question.

....

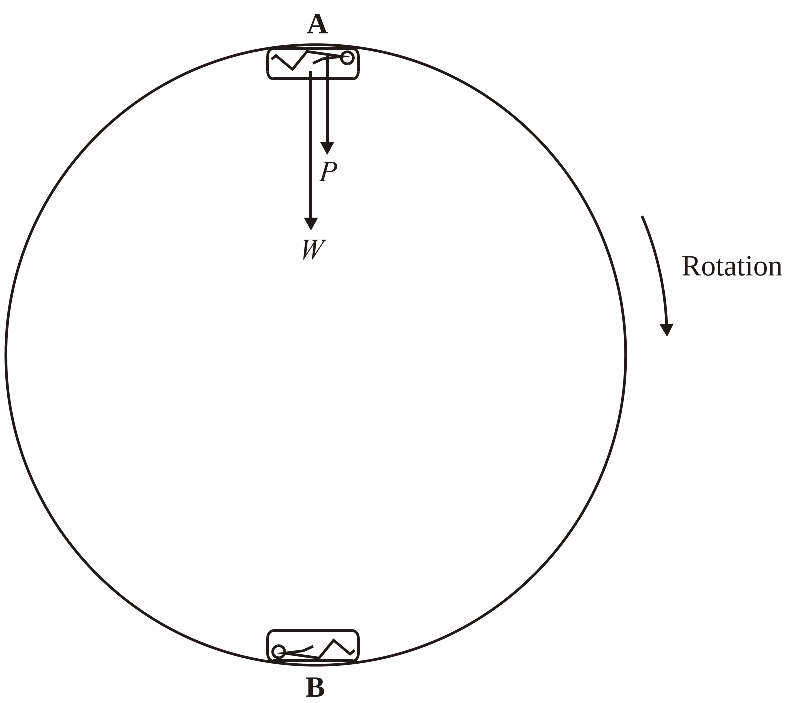
....

....

....

(2)
(Total 11 marks)

45. Riders on a theme park ride lie back in capsules round the rim of a large wheel. Initially the wheel is horizontal but it then moves into a vertical plane in which it rotates. The diagram shows the wheel when it is rotating in a vertical plane.



State the direction of the centripetal acceleration of the rider at **A**.

....

.... **(1)**

Explain why the resultant force on the rider at **A** has to be in this same direction.

....

....

.... **(1)**

The radius of the wheel is 8.0 m and the time for 1 revolution at maximum speed is 4.5 s. Show that at this speed the resultant force acting on a rider of mass 60 kg is about 900 N.

....

....

....

.... **(4)**

Calculate the weight *W* of the rider.

....

....

Weight = ...

(1)

Calculate *P*, the magnitude of the push from the capsule on the rider, when he is at point **A.**

....

....

Push = ...

(1)

Draw labelled arrows on the diagram to show the two principal forces acting on the rider when he is at point **B**.

(2)
(Total 10 marks)

46. As it moves through space, the Earth collides with small amounts of stationary material such as comet debris. After the collisions the pieces of material move with the Earth through space. As the Earth gives momentum to the material it collides with, it experiences a very small retarding force, and hence deceleration. Calculate this deceleration and comment on your answer.

Mass of extra material collected by the Earth each second = 7.0 kg
Speed of the Earth through space = 3.0×10^4 m s^{-1}
Mass of Earth = 6.0×10^{24} kg

(Allow one lined page)

(Total 5 marks)

47. Define **momentum** and state its unit.

Definition: ....

Unit: ....

(2)

A stationary nucleus of thorium-226 decays by alpha particle emission into radium.
The equation for the decay is:

$$^{226}_{90}\text{Th} \rightarrow \, ^{222}_{88}\text{Ra} + \, ^{4}_{2}\text{He}$$

State the value of the momentum of the thorium nucleus before the decay ....

(1)

After the decay, both the alpha particle and the radium nucleus are moving.

Which has the greater speed? Justify your answer.

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What can be said about the directions of travel of the two particles?

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(3)
(Total 6 marks)

48. A satellite S orbits the Earth once every 87 minutes.

Show that its angular speed is approximately 1×10^{-3} radians per second.

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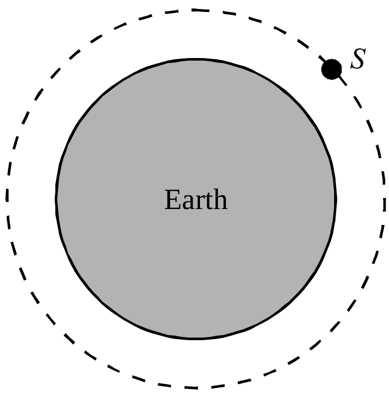
(2)

In the space on the right draw a free-body force diagram for the satellite in the position shown.



(1)

With reference to your free-body force diagram, explain why the satellite is accelerating.

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(1)

The radius of the satellite's orbit is 6500 km. Calculate the magnitude of its acceleration.

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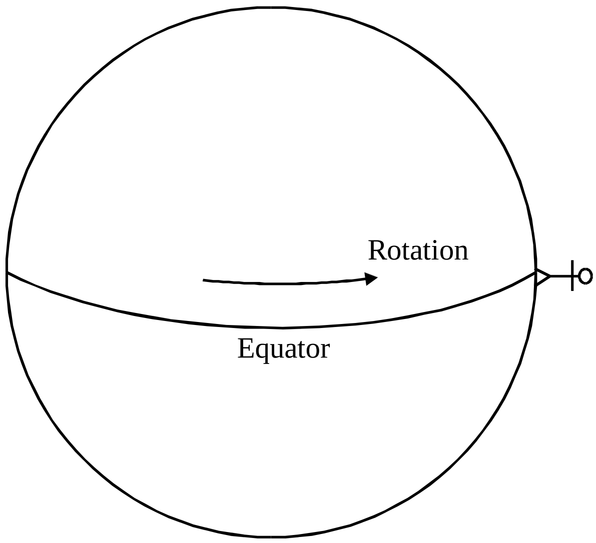
Acceleration = ...

(2)
(Total 6 marks)

49. A person at the equator of the Earth is moving, in a circle and therefore must have a centripetal acceleration.



Explain why a person moving in a circle must have an acceleration.

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(1)

Show that the centripetal acceleration of a person at the equator is about 0.03 m s^{-2}.
(Radius of the Earth = 6.4×10^6 m.)

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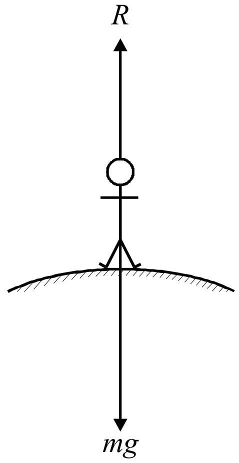
(3)

For a person standing at the equator, the force R from the ground is slightly different from their weight mg as shown below. State and explain which of these forces is the larger.



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(2)

The size of the force R provides a measure of the apparent strength of the gravitational field. Show that the apparent field strength g at the equator differs from that at the poles by about 0.3%.

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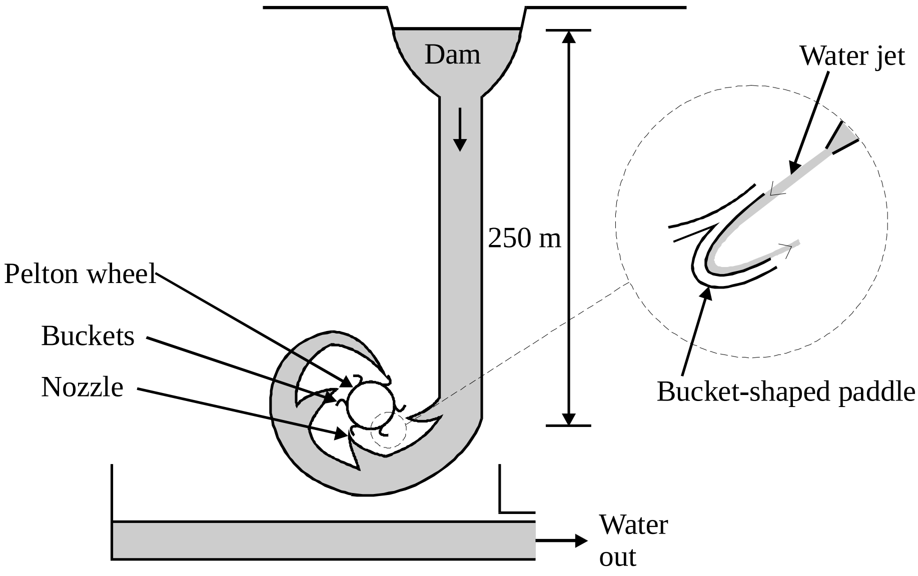
(1)
(Total 7 marks)

50. A hydroelectric power station in North Wales uses a Pelton wheel to convert water power to electricity. A Pelton wheel has a series of bucket-shaped paddles around the rim. The water is directed onto the paddles at high speed from a series of nozzles as shown in the diagram.



The Pelton wheel uses bucket-shaped paddles which are curved in order to deflect a water jet through 180°. By considering momentum, explain why this will provide more force than a jet of water hittinc, a flat paddle and simply falling off.

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(3)

The power station provides 500 kW of power. The water falls from a height of 250 m at a rate of 270 kg s^{-1}. Calculate the percentage efficiency of the percentage efficiency of the station.

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Efficiency = ...

(3)

The manufacturers of the Pelton wheel cast it from a mixture of iron, chromium and nickel. By adjusting the quantities used they were able to produce a corrosion-resistant wheel. State and explain **two** other desirable properties for the material from which the wheel is made.

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(4)

The power company invested one million pounds in this power station. There is an international agreement to encourage power generation using non-fossil fuels. Under this agreement the company will receive 4.74 p per kW h of electrical energy generated by the station.

Calculate the time, in years, to repay the initial investment, stating, one assumption made.

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Time = ...

Assumption: ....

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(4)
(Total 14 marks)

51. A space station orbits the Earth once every 91 minutes. Calculate the angular speed of the space station.

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Angular speed = ...

(3)

The space station orbit is 210 km above the surface of the Earth, which has a radius of 6370 km. Find the acceleration of the space station.

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Acceleration = ...

(3)

A box of mass 4.1 kg is located inside the space station. What is the size and direction of the resultant force acting on the box in the space station?

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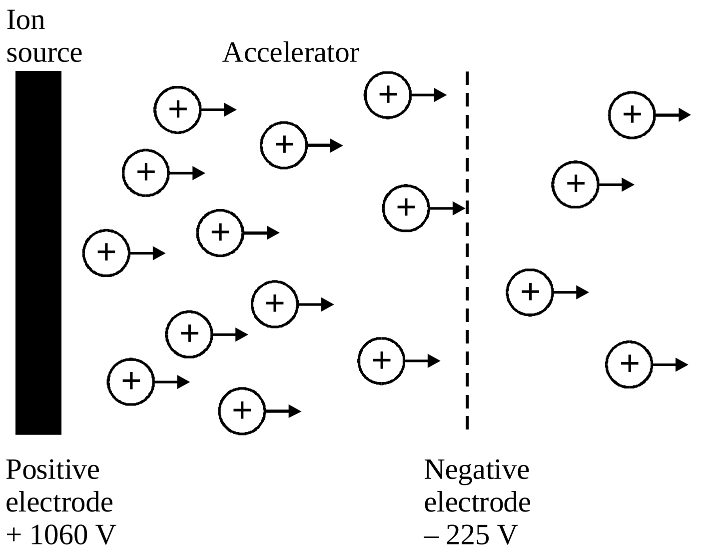
Resultant force = ...

(3)
(Total 9 marks)

52. In 1998 NASA launched the probe called Deep Space 1. Once in orbit, this probe was the first to use a solar powered ion drive to propel it on its mission.

The diagram shows the main features of the ion drive.



Atoms of xenon are ionised and then accelerated until they are ejected out of the rear of the probe, providing the means of propulsion.

Explain how the ions are accelerated.

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(2)

A xenon atom is ionised by the loss of a single electron. Show that its speed after being accelerated is about 4×10^4 m s^{-1}.

Mass of xenon ion = 2.20×10^{-25} kg.

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(4)

The mass of xenon ejected in one second is 2.10×10^{-6} kg. Calculate the thrust on the space probe.

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Thrust = ...

(3)

Simply firing xenon ions into space would leave the probe negatively charged. Suggest a reason why this would lead to reduced thrust.

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(1)

Chemical rockets eject their propellant at about a tenth of the velocity achieved by ion drives, but produce much greater thrust by ejecting more than a thousand kilograms per second.

Suggest why ion drives may be preferable for missions extending over long distances and periods of time.

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(2)
(Total 12 marks)

53. The following passage describing the inhabited part of the spaceship Discovery is adapted from *2001: A Space Odyssey* by Arthur C. Clarke.

> The space ship travelling through deep space contained a slowly rotating drum, ten metres in diameter. As it made one revolution every ten seconds, this produced an artificial gravity equal to that of the moon.

Diagram 1 below represents an astronaut standing on the surface of the moon.
Diagram 2 represents the astronaut standing inside the rotating drum as described in the passage.

Diagram 1

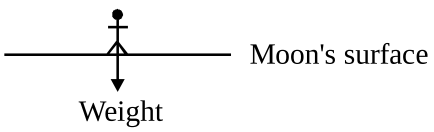
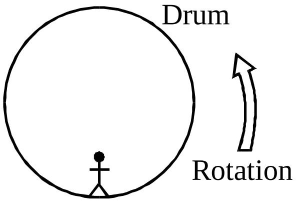


Diagram 2



Complete the diagrams by adding arrows to show any other forces acting on the astronaut.

(2)

Discuss the extent to which the astronaut in the rotating drum would experience an artificial gravity equivalent to the gravity of the moon.

Gravitational field strength on the moon = 1.6 N kg^{-1}.

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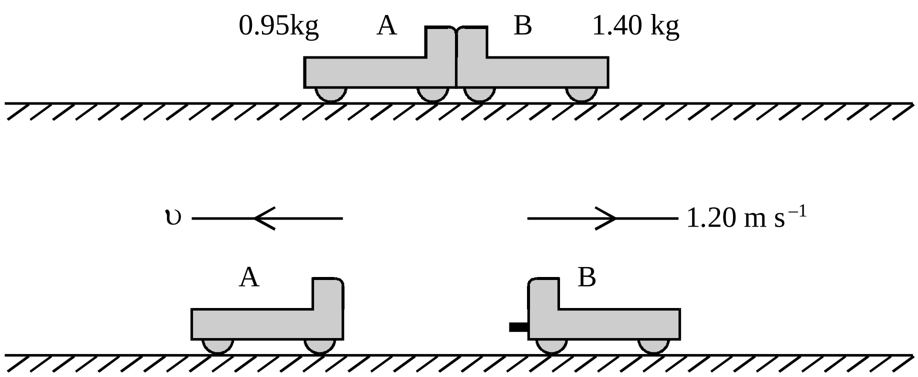
(5)
(Total 7 marks)

54. The diagram shows an experiment with two trolleys.



Initially the trolleys are at rest, in contact, on a horizontal bench. A spring-loaded piston is then released in one trolley, pushing the trolleys apart.

Describe an experimental technique by which you could determine accurately the speeds of the trolleys after they separate.

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(3)

State the total momentum of the trolleys as they move apart, and explain your answer.

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(2)

The masses of A and B are 0.95 kg and 1.40 kg respectively. B moves off at 1.20 m s^{-1}. Calculate the speed υ of A.

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Speed ....

(3)
(Total 8 marks)

55. It has been suggested that the centripetal force causing the Moon to orbit the Earth might be the result of electrical attraction and **not** gravitational attraction at all. Assuming the necessary force could arise as a result of the Earth and the Moon carrying equal charges (of opposite sign), show that the magnitude of these charges would have to be about 6×10^{13}C.

Data:	Mass of Moon	$= 7.4 \times 10^{22}$ kg
	Radius of Moon's orbit	$= 3.8 \times 10^{8}$ m
	Time of Moon's orbit	= 27 days

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(Total 6 marks)

56. A tennis ball connected to a long piece of string is swung around in a horizontal circle above the head of a pupil.

The pupil feels that there is a tension in the string and argues that for equilibrium there must be an outward “centrifugal” force acting on the ball. Criticise his argument and explain why there is a tension in the string.

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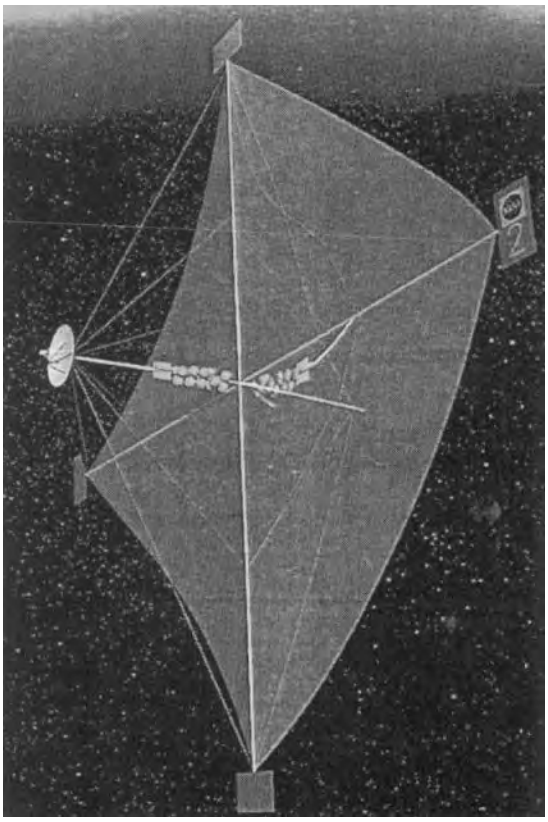
(5)

The pupil lets go of the string. Draw a free-body force diagram for the ball at the instant after release.

(1)
(Total 6 marks)

57. The diagram shows a solar sail, a possible method of propelling spacecraft.



NASA / MSFC Illustration (http://apod nasa.gov/apod/ap030308 html)

The solar sail uses "radiation pressure" caused by the momentum of photons of sunlight as they strike the sail. A sail with an area of 1.5×10^6 m^2 could be used to propel a spacecraft of mass 1.2×10^3 kg.

The energy E and momentum p of a photon are related by the expression $E = pc$, where c is the speed of light.

Calculate the total momentum of the photons striking 1 m^2 of sail in one second. Assume the solar radiation flux (intensity) is 1400 W m^{-2}.

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Momentum = ...

(2)

Hence find the force exerted on the whole sail if it is completely **non-reflective** so that all of the incident light is absorbed.

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Force = ...

(2)

Explain why this force is doubled if a totally **reflective** material is used.

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(2)

An advantage of this form of propulsion is that it can be used for long periods of time allowing high speeds to be attained. Calculate the maximum increase in speed during one week, using a **non-reflective** sail. Assume the solar radiation flux remains constant during this time. 1 week = 604 800 s.

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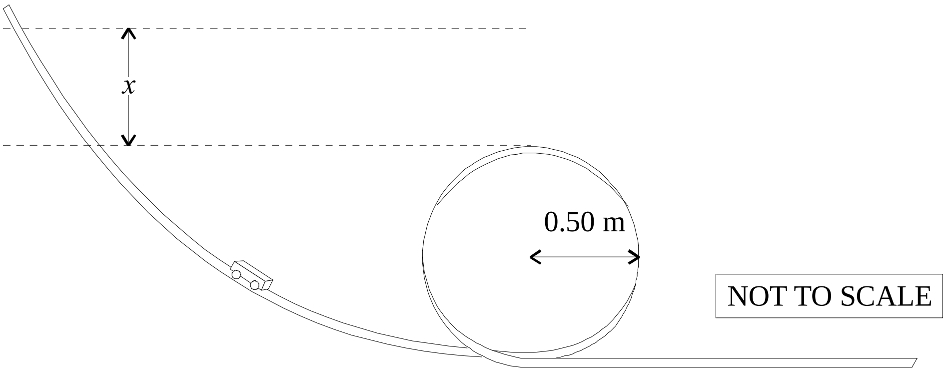
Maximum speed increase = ...

(3)

(Total 9 marks)

58. A model of a fairground ride consists of a track with a circular loop in it of radius 0.05 m. A model vehicle is rolling freely on a track which has negligible resistance to motion. The vehicle is raised to a certain height above the level of the top of the loop and then released.



The vehicle will not fall off the track at the top of the loop if its centripetal acceleration at that point is greater than g. Calculate the minimum height x above the top of the loop (marked x on the diagram) from which the vehicle can be released and still complete the loop while staying in contact with the track.

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x = ...

(Total 5 marks)

59. State the principle of conservation of linear momentum.

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(2)

This principle is a consequence of two of Newton’s laws of motion. Which two?

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(1)

In one experiment to test the principle of conservation of momentum, a moving trolley collides with and sticks to an identical trolley which is initially at rest on a horizontal bench. Describe how you would check whether momentum was conserved.

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(4)

A student performing this experiment found that the final momentum was always slightly smaller than the initial momentum. Assuming that the measuring technique was accurate, suggest a reason for this.

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(1)

In a test laboratory, a car is crashed into a concrete wall and comes to rest. There is no damage to the wall. Explain how the principle of conservation of momentum applies to this situation.

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(2)
(Total 10 marks)

60. A car travelling at 30 m s^{-1} collides with a wall. The driver, wearing a seatbelt, is brought to rest in 0.070 s.

The driver has a mass of 50kg. Calculate the momentum of the driver before the crash.

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Momentum = ...

(2)

Calculate the average resultant force exerted on the driver during impact.

....

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....

Average resultant force = ...

(3)

Explain why the resultant force is not the same as the force exerted on the driver by the seatbelt.

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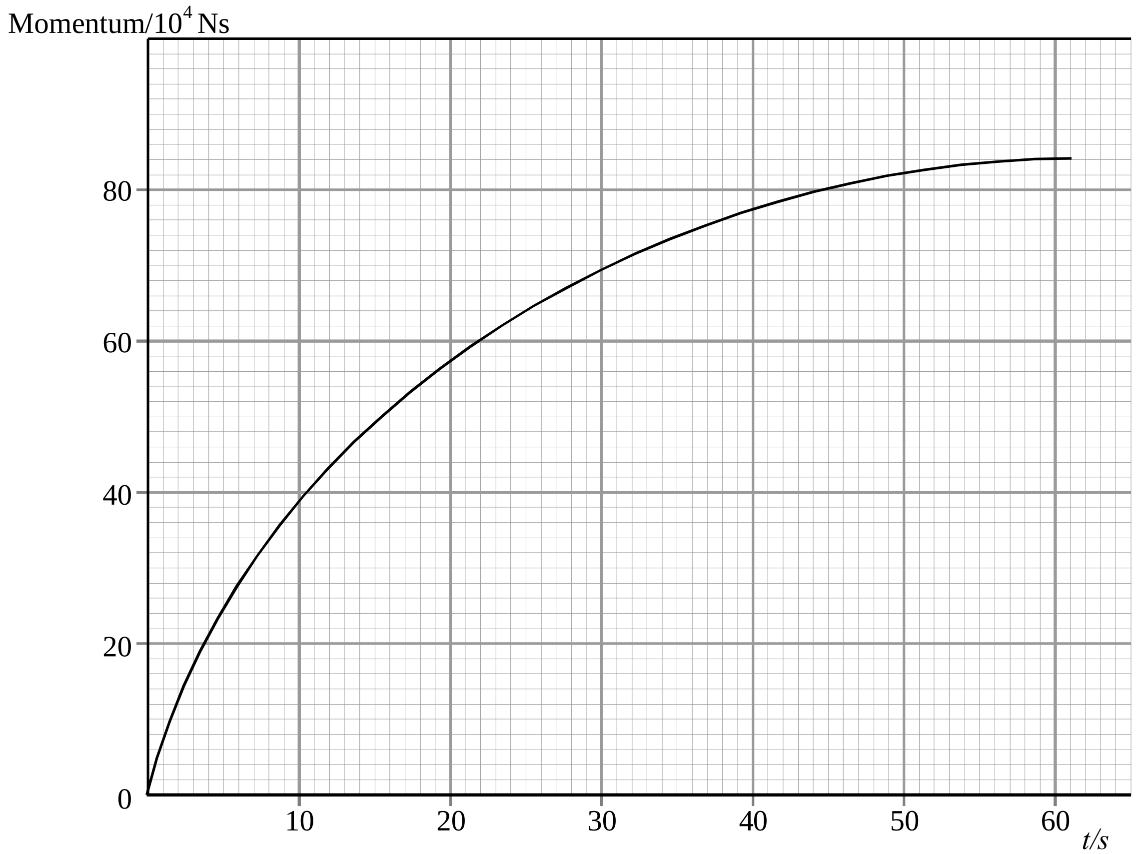
(1)
(Total 6 marks)

61. The graph below shows how the momentum of this lorry varies over the first Minute.



Define **momentum**.

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(1)

State the physical quantity represented by the slope of this graph.

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(1)

Determine the magnitude of this quantity at $t = 20$ s.

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(2)

Explain the shape of this graph.

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(2)
(Total 7 marks)

62. According to Newton's second law of motion, the rate of change of momentum of an object is proportional to the resultant force F acting on it. Show how this statement leads to the equation

$$F = ma$$

where m is the mass and a the acceleration of the object.

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(4)

When jumping from a height on to a hard surface, it is advisable to bend one’s knees on landing.

How does bending the knees affect the time one takes to come to rest?

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(1)

With reference to Newton’s second law, explain why it is a good idea to bend one’s knees.

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(2)
(Total 7 marks)

63. Explain why a body moving at constant speed in a circular path needs a resultant force acting on it.

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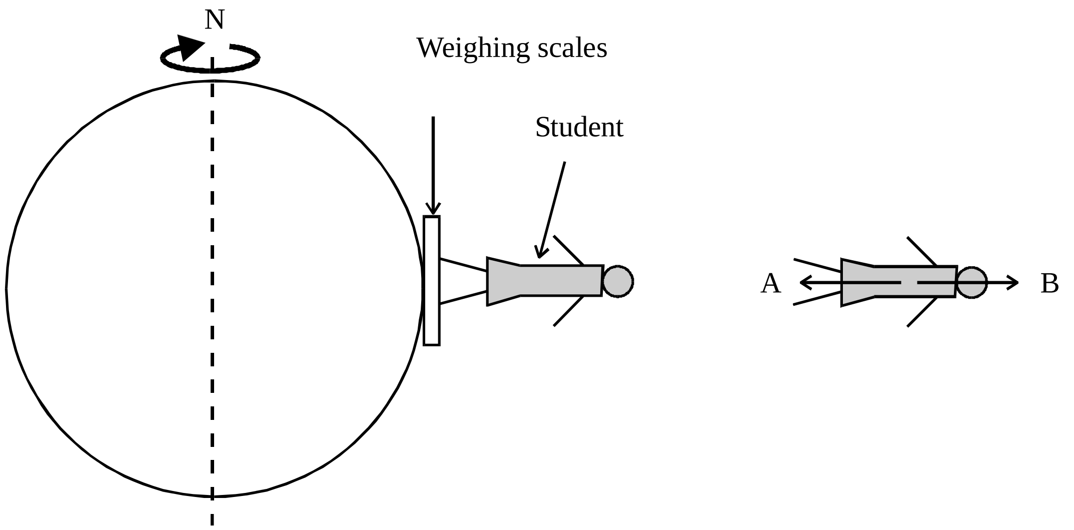
(2)

The diagram shows a student at the equator standing on a set of weighing scales, and a free-body force diagram for the student.



Identify the bodies applying forces A and B.

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(2)

Because of the Earth's daily rotation the student is performing circular motion about the Earth's axis. Calculate the angular speed of the student.

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Angular speed =................................

(2)

The radius of the Earth is 6400 km. The student's mass is 55 kg. Calculate the resultant force on the student.

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Resultant force =......................................

(3)

Force A is 539 N. Calculate the value of force B.

....

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Force B =...................................

State, with a reason, the force indicated by the weighing scales.

....

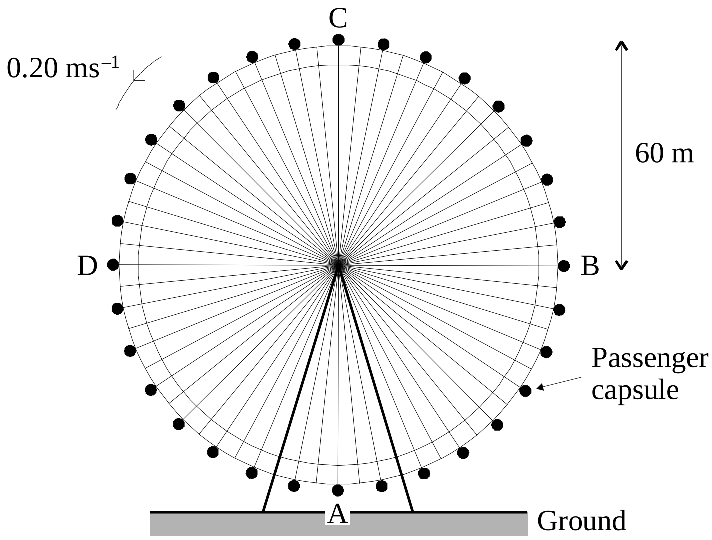
....

(3)

(Total 12 marks)

64. The ‘London Eye’ is a large wheel which rotates at a slow steady speed in a vertical plane about a fixed horizontal axis. A total of 800 passengers can ride in 32 capsules equally spaced around the rim.

A simplified diagram is shown below.



On the wheel, the passengers travel at a speed of about 0.20 m s^{-1} round a circle of radius 60 m. Calculate how long the wheel takes to make one complete revolution.

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....

Time = ...

(2)

What is the change in the passenger’s velocity when he travels from point B to point D?

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....

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(2)

When one particular passenger ascends from point A to point C his gravitational potential energy increases by 80 kJ. Calculate his mass.

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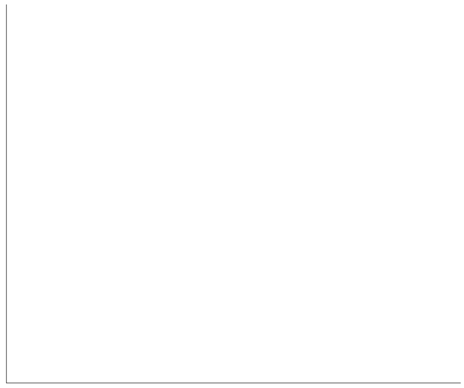
Mass =..........................

(3)

On the axes below sketch a graph showing how the passenger's gravitational potential energy would vary with time as he ascended from A to C. Add a scale to each axis.



(3)

Discuss whether it is necessary for the motor driving the wheel to supply this gravitational potential energy.

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(2)
(Total 12 marks)

65. Define linear momentum.

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(1)

The principle of conservation of linear momentum is a consequence of Newton's laws of motion. An examination candidate is asked to explain this, using a collision between two trolleys as an example. He gives the following answer, which is correct but incomplete. The lines of his answer are numbered on the left for reference.

1. During the collision the trolleys push each other.

2. These forces are of the same size but in opposite directions.

3. As a result, the momentum of one trolley must increase at the same rate as the momentum of the other decreases.

4. Therefore the total momentum of the two trolleys must remain constant.

In which line of his argument is the candidate using Newton's second law?

....

(1)

In which line is he using Newton's third law?

....

(1)

The student is making one important assumption which he has not stated. State this assumption. Explain at what point it comes into the argument.

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(2)

Describe how you could check experimentally that momentum is conserved in a collision between two trolleys.

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(4)
(Total 9 marks)

66. Fast modern passenger and car ferries are often twin-hull boats, propelled using water jets instead of conventional propellers. A pumping system throws water out backwards at speed. One such ferry is the Stena Lynx II, which sails between Fishguard in Wales and Rosslare in Ireland.

Some data about the Stena Lynx II:

Resistive forces at cruising speed	$= 8.0 \times 10^5$ N
Mass of water per second ejected by the jets	$= 60\ 000$kg s^{-1}

Show that water must be thrown backwards at about 13 m s^{-1} while the boat is maintaining cruising speed.

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(3)

The pumping system converts energy which is expended in two main ways: working against resistive forces and giving kinetic energy to the water thrown backwards.

Calculate the power expended against the resistive forces at the cruising speed of 20 ms^{-1}.

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Power = …………………………

(2)

Calculate the rate at which the water in the jets gains kinetic energy.

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Rate = …………………………

(2)

Hence show that the overall efficiency of the pumping system at cruising speed is about 40%.

Data:

Fuel consumption of pumping system at cruising speed = 1.6 litres/second
1 litre of fuel provides 3.4×10^7 J of energy when burnt

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(3)
(Total 10 marks)

67. A satellite orbits the Earth once every 120 minutes. Calculate the satellite's angular speed.

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....

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angular speed = ...

(2)

Draw a free-body force diagram for the satellite.

(1)

The satellite is in a state of free fall. What is meant by the term *free fall?* How can the height of the satellite stay constant if the satellite is in free fall?

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(3)
(Total 6 marks)