Questions

Q1.

A DVD is rotating at 570 rotations per minute.

What is its angular velocity in radians per second?

(1)

- ☐ **A** 1.5
- ☐ **B** 10
- ☐ **C** 60
- ☐ **D** 3600

(Total for question = 1 mark)

Q2.

The International Space Station (ISS) completes 16 orbits of the Earth every 24 hours.
The ISS is 330 km above the surface of the Earth.

(a) Show that the angular velocity of the ISS around the Earth is about 1×10^{-3} rad s^{-1}.

(2)

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(b) Calculate the acceleration of the ISS in this orbit.

radius of Earth = 6400 km

(2)

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Acceleration of the ISS = ...

(Total for question = 4 marks)

Q3. The photograph shows the drum inside a washing machine.

The drum is a hollow metal cylinder with a series of holes through its surface.
During the spin cycle the drum rotates at 1400 revolutions per minute to separate the water from the wet clothes.

(a) (i) Show that the speed of the point X on the rotating drum is about 35 m s^{-1}.

diameter of drum = 0.480 m

(2)

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(ii) A shirt button remains at a single point on the drum as the drum spins.
Calculate the centripetal force acting on the shirt button.
mass of shirt button = 1.4 g

(2)

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Centripetal force = ...

(b) Explain how the drum spinning separates water from the wet clothes.

(2)

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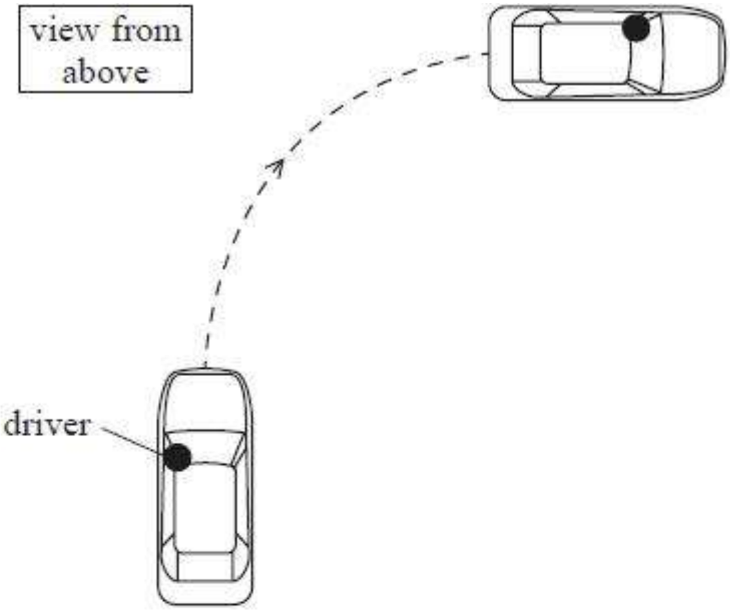
(Total for question = 6 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

A driver steers a car to the right as shown. The driver remains at the same position in the car as the car changes direction.



Which of the following does the driver experience as the car moves in the circular path?

☐ **A** A force to his left and a force to his right.

☐ **B** A resultant force to his left.

☐ **C** A resultant force to his right.

☐ **D** No resultant force.

(Total for question = 1 mark)

Q5. Hammer Throwing is an Olympic sport. The sport uses a metal sphere attached to a chain. The athlete holds the chain and spins around to give the sphere a large angular velocity.

When the sphere is released it travels in a parabolic path through the air and lands on the ground.

(a) Explain why, at the instant of release, the sphere stops travelling in a circular path.

(2)

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(b) The sphere has a mass of 7.3 kg. The athlete moves the sphere through a circle of radius 1.7 m. The speed of the sphere, at the instant of release, is 18 m s^{-1}.

(i) Calculate the angular velocity of the sphere.

(2)

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Angular velocity = ...

(ii) Assuming that both the circle and chain are horizontal, calculate the force that the athlete exerts on the chain just before its release.

(2)

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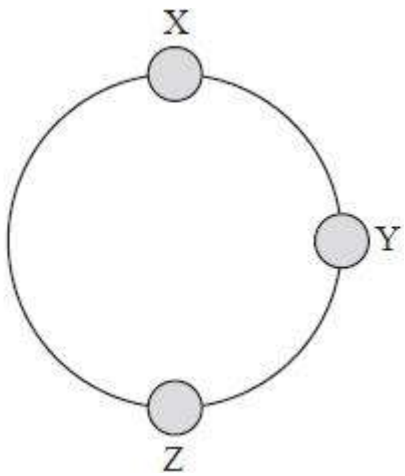
Force = ...

(c) The diagram below shows the sphere moving in a vertical circle.



(i) Draw arrows on the diagram to show the direction of the centripetal force on the sphere at each of the positions X, Y and Z.

(1)

*(ii) The tension in the chain varies as the sphere moves in the vertical circle.

State the position, X, Y or Z, at which the tension will be a maximum and the position, X, Y or Z, where it will be a minimum. Explain your answers.

(4)

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(Total for question = 11 marks)

Q6. The International Space Station (ISS) is in orbit at a height of 400 km above the Earth's surface. The ISS completes 15.5 orbits in 24 hours.

(a) Calculate the angular velocity of the ISS in radians per second.

(2)

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Angular velocity = ... rad s^{-1}

*(b) A student suggests:

"*The ISS is travelling at a constant speed, so, according to Newton's laws, there will be no resultant force acting on it.*"
Criticise this suggestion.

(3)

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(c) Calculate the magnitude of the centripetal force acting on the ISS.

mass of ISS = 4.19×10^5 kg
radius of Earth = 6400 km

(2)

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Force = ...

(Total for question = 7 marks)

Q7.

When an object moves in a circular path at constant speed, a resultant force is required.

(a) State why a resultant force is required and the direction of this force.

(2)

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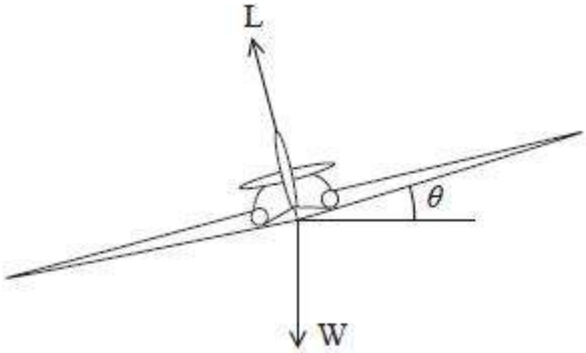
(b) When an aeroplane is flying there is an upward force called lift which acts at right angles to the wings. When the aeroplane is flying in a straight line, the lift force is equal to the weight of the aeroplane.

The diagram shows an aeroplane that is moving in a horizontal circle at constant speed.



*(i) Explain, in terms of forces, why the aeroplane is able to fly in a circular path.

(2)

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(ii) The aeroplane has a mass of 2.4×10^6 kg and is flying in a horizontal circle at a speed of 85 m s^{-1} when θ is 25°.
By considering both the horizontal and vertical motion, calculate the radius of the circular path of the aeroplane.

(4)

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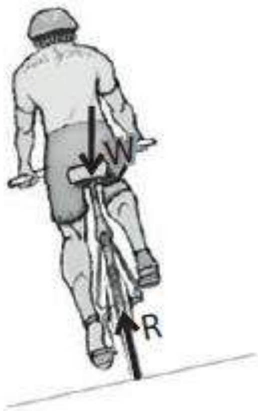
Radius = ...

Q8.

The photograph shows part of the cycling track used in the London 2012 Olympic Games. On the bend the track is banked so that the outside of the track is higher than the inside of the track.

The diagram shows the forces *R* and *W* acting on a cyclist travelling at a constant speed around the bend.



(a) Explain why there must be a resultant force acting on the cyclist.

(2)

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(b) Explain why a banked track is an advantage to cyclists.

(2)

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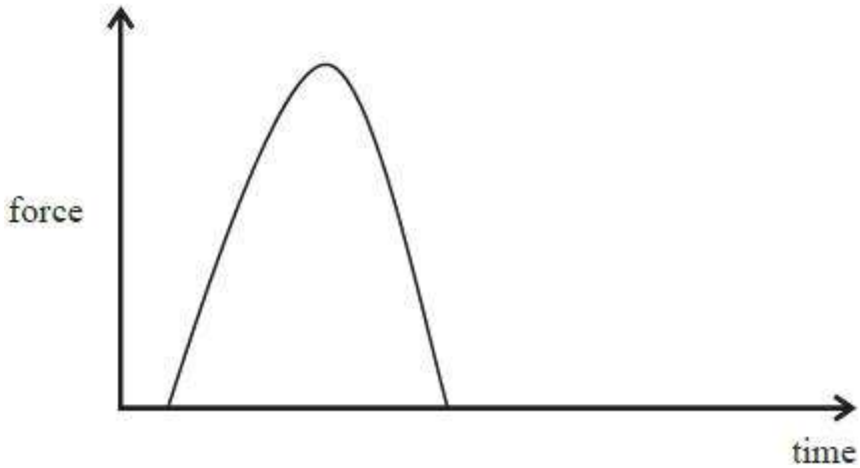
(c) An inflatable airbag helmet for cyclists has been designed to prevent head injuries. It is worn like a scarf around the neck. In-built sensors detect when the cyclist is involved in a crash and inflate the airbag over the cyclist's head in 0.1 s.

The graph shows how the force on a cyclist's head during a collision varies with time when an airbag is not used.



Add to the axes, the graph that shows how the force on a cyclist's head during a collision varies with time when the airbag is used.

Justify the shape of your graph.

(3)

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(Total for question = 7 marks)

Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is **C** A is not the correct answer because it is $570 \div (60 \times 2\pi)$ B is not the correct answer because it is $570 \div 60$ D is not the correct answer because it is $570 \times 2\pi$)	**1**

Q2.

Question Number	Answer		Mark
(a)	Use of $\omega = \frac{2\pi}{T}$	(1)	
	$\omega = 1.2 \times 10^{-3}$ (rad s^{-1})	(1)	**2**
	Example of calculation $\omega = \frac{2\pi \times 16 \text{ rad}}{(24 \times 60 \times 60 \text{ s})} = 1.16 \times 10^{-3}$ rad s^{-1}		
(b)	Use of $a = r\omega^2$ **Or** use of $v = r\omega$ **and** $a = v^2/r$ (ecf from (a))	(1)	
	$a = 9.7$ m s^{-2} ("show that" answer gives 6.7 m s^{-2}) (using $\omega = 1.16 \times 10^{-3}$ gives 9.1 m s^{-2})	(1)	**2**
	Example of calculation $a = (330 + 6400) \times 10^3 \text{ m} \times (1.2 \times 10^{-3} \text{rad s}^{-1})^2 = 9.7$ m s^{-2}		
	Total for question		**4**

Q3.

Question Number	Answer		Mark
(a)(i)	Use of $v = 2\pi r/T$ **Or** Use of $v = 2\pi rf$ **Or** Use of $v = \omega r$ and $\omega = 2\pi/T$ $v = 35.2$ (m s^{-1}) <u>Example of calculation</u> $v = 2\pi \times 0.240$ m / (60 / 1400) s $v = 35.2$ m s^{-1}	(1) (1)	2
(a)(ii)	Use of $F = mv^2/r$ **Or** $F = m\omega^2 r$ $F = 7.2$ N (allow full ecf for answer in a) ('Show that' value gives 7.1 N) <u>Example of calculation</u> $F = 0.0014$ kg $\times$ (35.2 m s^{-1})^2 / 0.240 m $F = 7.23$ N	(1) (1)	2
(b)	Water has no resultant/centripetal force **Or** The clothes experience a centripetal force from the drum **Or** The clothes experience a resultant force towards the centre of the drum Water continues its motion in a straight line **Or** Water leaves drum along a tangent	(1) (1)	2
	Total for question		**6**

Q4.

Question Number	Answer	Mark
	C	1

Q5.

Question Number	Answer		Mark
(a)	(when released) there is no (horizontal) force acting Force is needed to change direction **Or** sphere travels in a straight/tangential line	(1) (1)	 **2**
(b)(i)	Use of $v = r\omega$ $\omega = 11$ rad s^{-1} Example of calculation $\omega = 18$ m s^{-1}/ 1.7 m $\omega = 10.6$ rad s^{-1}	(1) (1)	 **2**
(b)(ii)	Use of $F = mv^2/r$ **Or** $F = mr\omega^2$ **Or** $F = mv\omega$ $F = 1400$ N ecf from (b)(i) (MP1 not awarded if ω from (i) is used as v) Example of calculation $F = 7.3$ kg × (18 m s^{-1})^2 / 1.7 m $F = 1390$ N	(1) (1)	 **2**
(c)(i)	Three arrows all pointing to the centre of the circle (accept free hand and lines of varying length but they must touch the spheres)	(1)	**1**
* (c)(ii)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) The centripetal force is the resultant force Maximum at Z / bottom **and** Minimum at X / top At Z Tension T greater than weight (accept $T - W = mv^2/r$ or $T = W + mv^2/r$) At X tension force is less than the weight. (accept $W + T = mv^2/r$ or $T = mv^2/r - W$) (The symbols W mg T mv^2/r $mr\omega^2$ and F_C accepted without definitions but any other symbols must be defined) This is a qwc question so a bald statement of the equations can score marks but to get full marks there must be clear explanation	 (1) (1) (1) (1)	 **4**
	Total for Question		**11**

Q6.

Question Number	Answer	Mark
(a)	Use of $\omega = \frac{2\pi}{T}$ **Or** Use of $\omega = \theta/t$ (1) $\omega = 1.13 \times 10^{-3}$ (rad s^{-1}) (1) <u>Example of calculation</u> $\omega = \frac{2\pi \times 15.5}{(24 \times 60 \times 60\ s)} = 1.13 \times 10^{-3}$ (rad s^{-1})	**2**
(b)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) (although speed is constant) velocity is changing since direction is changing (1) Therefore ISS is accelerating (1) So (by N1/2) there must be a resultant / centripetal force (1)	**3**
(c)	Use of $F = mr\omega^2$ **Or** $F = \frac{mv^2}{r}$ and $v = r\omega$ **Or** use $F \propto \frac{1}{r^2}$ (1) $F = 3.6 \times 10^6$ N ecf value of w from (a) (1) <u>Example of calculation</u> $F = 4.19 \times 10^5\ kg \times (6.4 \times 10^6 m + 4 \times 10^5 m) \times (1.13 \times 10^{-3}\ rad\ s^{-1})^2$ $= 3.6 \times 10^6$ N	**2**
	Total for question	**7**

Q7.

Question Number	Answer		Mark
(a)	Velocity/direction changing **Or** (object is) accelerating Force towards centre (of circle)	(1) (1)	**2**
*(b)(i)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Identifies a horizontal component of lift **Or** refers to $L \sin \theta$ Which acts as a centripetal force **Or** which provides a centripetal acceleration **Or** force perpendicular to velocity of plane so acts to centre (of circle) (MP2 **dependent mark** and only awarded for reference to a horizontal force)	 (1) (1)	**2**
(b)(ii)	Resolve vertically $L\cos \theta = mg$ Resolve horizontally $L\sin \theta = mv^2/r$ Use their value of L in their horizontal equation **Or** uses $\tan \theta = v^2/rg$ $r = 1.6$ km <u>Example of calculation</u> $L\cos \theta = mg$ $L = 2.4 \times 10^6 \text{ kg} \times 9.81 \text{ kg N}^{-1} / \cos 25° = 2.6 \times 10^7 \text{ N}$ horizontally $L\sin \theta = mv^2/r$ $r = mv^2 / L\sin \theta = 2.4 \times 10^6 \text{ kg} \times 85^2 \text{ m}^2 \text{ s}^{-2} / 2.6 \times 10^7 \text{ N} \times \sin 25°$ $r = 1578$ m	(1) (1) (1) (1)	**4**
	Total for Question		**8**

Q8.

Question Number	Answer		Mark
(a)	Direction changing **Or** the velocity changes Therefore (cyclist) accelerates	(1) (1)	**2**
(b)	The horizontal component of reaction force acts towards centre of rotation **Or** The horizontal component of R provides/contributes to the centripetal force The cyclist can go faster	(1) (1)	**2**
(c)	Graph drawn: has a smaller maximum force the change is over a longer time Justification: With airbag the rate of change of momentum is smaller **Or** acceleration is smaller **Or** Area(s) under graph(s) the same (accept impulse the same)	 (1) (1) (1)	**3**
	Total for question		**7**