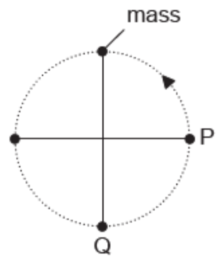
Uniform Circular Motion Practice Qs *[54 marks]*

1. A mass attached to a string rotates in a gravitational field with a constant period in a vertical plane. *[1 mark]*



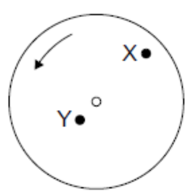
How do the tension in the string and the kinetic energy of the mass compare at P and Q?

	Tension in the string	Kinetic energy of mass
A.	greater at P than Q	greater at Q than P
B.	greater at Q than P	greater at Q than P
C.	greater at P than Q	same at Q and P
D.	greater at Q than P	same at Q and P

Markscheme

B

2. A horizontal disc rotates uniformly at a constant angular velocity about a central axis normal to the plane of the disc. *[1 mark]*



Point X is a distance 2L from the centre of the disc. Point Y is a distance L from the centre of the disc. Point Y has a linear speed v and a centripetal acceleration a.

What is the linear speed and centripetal acceleration of point X?

	Linear speed of X	Centripetal acceleration of X
A.	v	a
B.	$2v$	$2a$
C.	v	$2a$
D.	$2v$	$4a$

Markscheme

B

3. An object of constant mass is tied to the end of a rope of length *l* and made to move in a horizontal circle. The speed of the object is increased until the rope breaks at speed *v*. The length of the rope is then changed. At what other combination of rope length and speed will the rope break? *[1 mark]*

	Rope length	Speed
A.	$4l$	$2v$
B.	$2l$	v
C.	$2l$	$\frac{v}{2}$
D.	$4l$	$\frac{v}{2}$

Markscheme

A

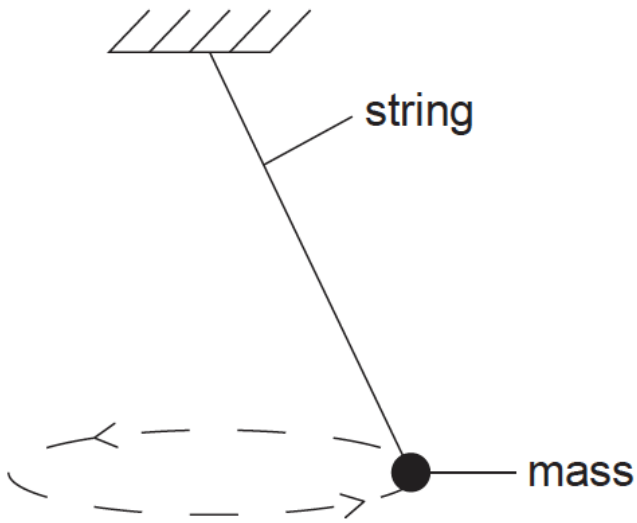
4. Two satellites of mass *m* and 2*m* orbit a planet at the same orbit radius. If *F* is the force exerted on the satellite of mass *m* by the planet and a is the centripetal acceleration of this satellite, what is the force and acceleration of the satellite with mass 2*m*? *[1 mark]*

	Force	Acceleration
A.	$2F$	a
B.	$2F$	$\frac{a}{2}$
C.	F	a
D.	F	$\frac{a}{2}$

Markscheme

A

5. A mass is suspended by a string from a fixed point. The mass moves with constant speed along a circular path in a horizontal plane. *[1 mark]*



The resultant force acting on the mass is

A. zero.

B. directed upwards along the string.

C. directed towards the centre of the circular path.

D. in the same direction as the velocity of the mass.

Markscheme

C

6. An object rotates in a horizontal circle when acted on by a centripetal force *F*. What is the centripetal force acting on the object when the radius of the circle doubles and the kinetic energy of the object halves? *[1 mark]*

A. $\frac{F}{4}$

B. $\frac{F}{2}$

C. *F*

D. 4*F*

Markscheme

A

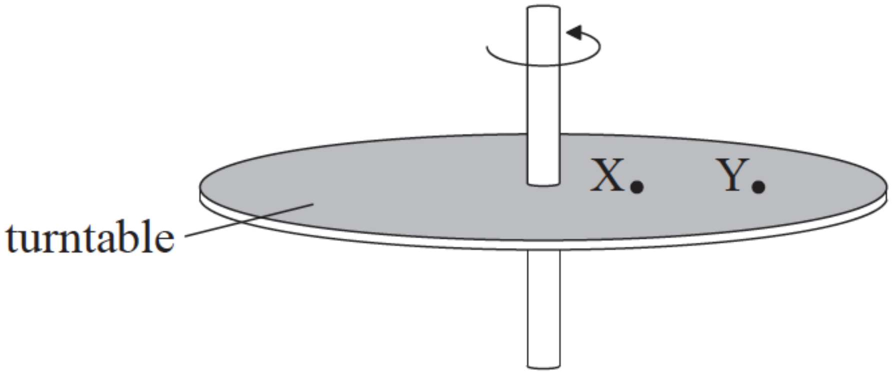
7. The maximum speed with which a car can take a circular turn of radius *R* is *v*. The maximum speed with which the same car, under the same conditions, can take a circular turn of radius 2*R* is *[1 mark]*

A. 2*v*.
B. $v\sqrt{2}$.
C. 4*v*.
D. $2v\sqrt{2}$.

Markscheme

B

8. Two particles, X and Y, are attached to the surface of a horizontally mounted turntable. *[1 mark]*



The turntable rotates uniformly about a vertical axis. The magnitude of the linear velocity of X is *v* and the magnitude of its acceleration is *a*. Which of the following correctly compares the magnitude of the velocity of Y and the magnitude of the acceleration of Y with *v* and *a* respectively?

	Magnitude of velocity of Y	Magnitude of acceleration of Y
A.	equal to *v*	less than *a*
B.	greater than *v*	less than *a*
C.	equal to *v*	greater than *a*
D.	greater than *v*	greater than *a*

Markscheme

D

9. A body moves with uniform speed around a circle of radius *r*. The period of the motion is *T*. What is the speed of the body? *[1 mark]*

A. $\frac{2\pi r}{T}$

B. $\frac{2\pi T}{r}$

C. Zero

D. $\frac{\pi r^2}{T}$

Markscheme

A

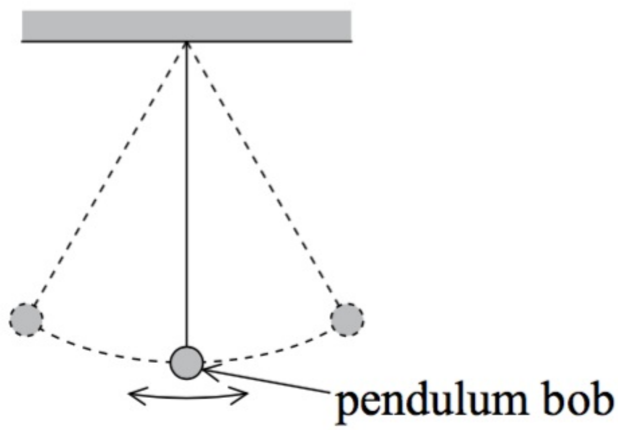
10. A car on a road follows a horizontal circular path at constant speed. Which of the following correctly identifies the origin and the direction of the net force on the car? *[1 mark]*

	Origin	Direction
A.	car engine	toward centre of circle
B.	car engine	away from centre of circle
C.	friction between car tyres and road	away from centre of circle
D.	friction between car tyres and road	toward centre of circle

Markscheme

D

11. A pendulum bob is attached to a light string and is swinging in a vertical plane. *[1 mark]*



At the lowest point of the motion, the magnitude of the tension in the string is

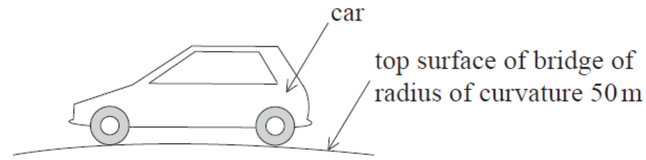
A. less than the weight of the mass of the pendulum bob.
B. zero.
C. greater than the weight of the mass of the pendulum bob.
D. equal to the weight of the mass of the pendulum bob.

Markscheme

C

This question is about circular motion.

The diagram shows a car moving at a constant speed over a curved bridge. At the position shown, the top surface of the bridge has a radius of curvature of 50 m.



12a. Explain why the car is accelerating even though it is moving with a constant speed. *[2 marks]*

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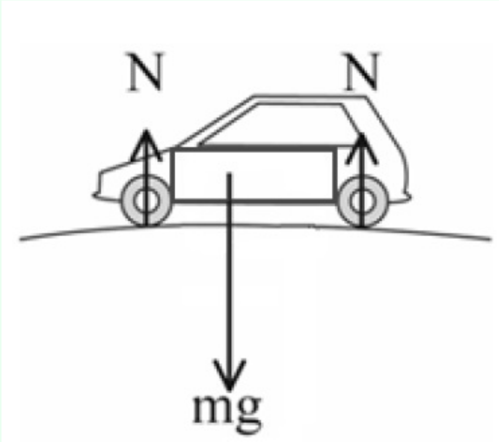
Markscheme

direction changing;

velocity changing so accelerating;

12b. On the diagram, draw and label the vertical forces acting on the car in the position shown. *[2 marks]*

Markscheme



weight/gravitational force/mg/w/F_w/F_g and reaction/normal reaction/perpendicular contact force/N/R/F_N/F_R both labelled; *(do not allow "gravity" for "weight".)*

weight between wheels (in box) from centre of mass and reactions at both wheels / single reaction acting along same line of action as the weight;

Judge by eye. Look for reasonably vertical lines with weight force longer than (sum of) reaction(s). Extra forces (eg centripetal force) loses the second mark.

12c. Calculate the maximum speed at which the car will stay in contact with the bridge. *[3 marks]*

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Markscheme

$g = \frac{v^2}{r}$;
$v = \sqrt{50 \times 9.8}$;

22(ms^{-1});

*Allow **[3]** for a bald correct answer.*

13. A car travels in a horizontal circle at constant speed. At any instant the resultant horizontal force acting on the car is *[1 mark]*

A. zero.
B. in the direction of travel of the car.
C. directed out from the centre of the circle.
D. directed towards the centre of the circle.

Markscheme

D

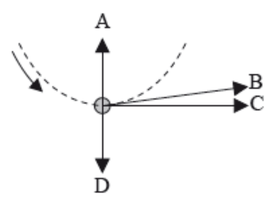
14. A cyclist rides around a circular track at a uniform speed. Which of the following correctly gives the net horizontal force on the cyclist at any given instant of time? *[1 mark]*

	Net horizontal force along direction of motion	Net horizontal force normal to direction of motion
A.	zero	zero
B.	zero	non zero
C.	non zero	zero
D.	non zero	non zero

Markscheme

B

15. A ball is tied to a string and rotated at a uniform speed in a vertical plane. The diagram shows the ball at its lowest position. Which arrow shows the direction of the net force acting on the ball? *[1 mark]*

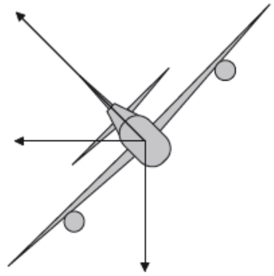


Markscheme

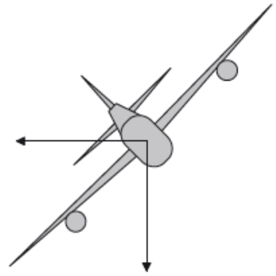
A

16. An aircraft is flying at constant speed in a horizontal circle. Which of the following diagrams best illustrates the forces acting on the aircraft in the vertical plane? *[1 mark]*

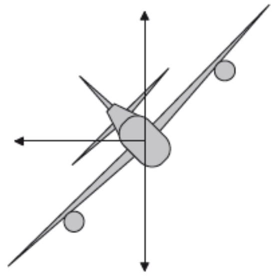
A.



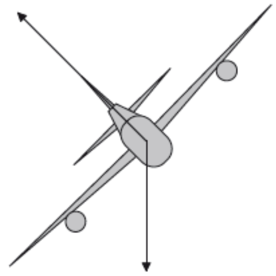
B.



C.



D.

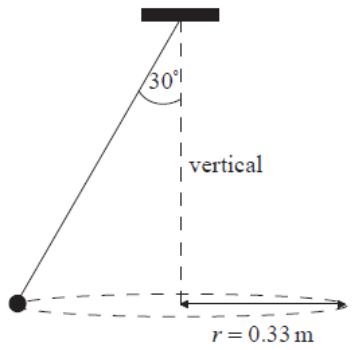


Markscheme

D

This question is about circular motion.

A ball of mass 0.25 kg is attached to a string and is made to rotate with constant speed *v* along a horizontal circle of radius *r* = 0.33m. The string is attached to the ceiling and makes an angle of 30° with the vertical.



17a. (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[4 marks]*

(ii) State and explain whether the ball is in equilibrium.

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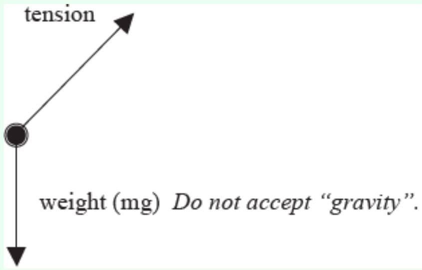
Markscheme

(i) ***[1]*** each for correct arrow and (any reasonable) labelling;



*Award **[1 max]** for arrows in correct direction but not starting at the ball.*

(ii) no;
because the two forces on the ball can never cancel out / there is a net force on the ball / the ball moves in a circle / the ball has acceleration/it is changing direction;
*Award **[0]** for correct answer with no or wrong argument.*

17b. Determine the speed of rotation of the ball. *[3 marks]*

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Markscheme

$T\left(=\frac{mg}{\cos 30^\circ}\right)=2.832\text{N}$;
$\frac{mv^2}{r}=T\sin 30^\circ$;
$v=\left(\sqrt{\frac{Tr\sin 30^\circ}{m}}=\sqrt{\frac{2.832\times 0.33\times\sin 30^\circ}{0.25}}\right)=1.4\text{ms}^{-1}$;

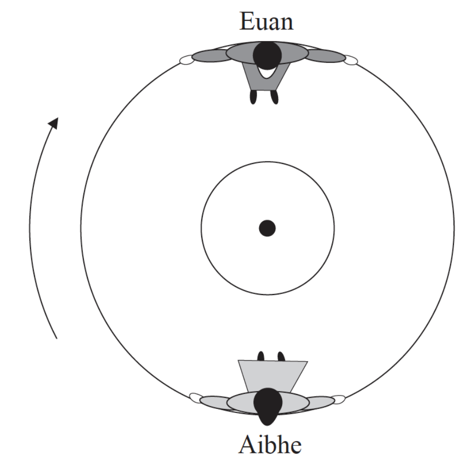
or

$T\cos 30^\circ=mg$;
$T\sin 30^\circ=\frac{mv^2}{r}$;
$v=\left(\sqrt{gr\tan 30^\circ}=\sqrt{9.81\times 0.33\times\tan 30^\circ}\right)=1.4\text{ms}^{-1}$;

This question is in **two** parts. **Part 1** is about two children on a merry-go-round. **Part 2** is about electric circuits.

Part 1 Two children on a merry-go-round

Aibhe and Euan are sitting on opposite sides of a merry-go-round, which is rotating at constant speed around a fixed centre. The diagram below shows the view from above.



Aibhe is moving at speed 1.0ms^{-1} relative to the ground.

18a. Determine the magnitude of the velocity of Aibhe relative to *[2 marks]*

(i) Euan.

(ii) the centre of the merry-go-round.

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Markscheme

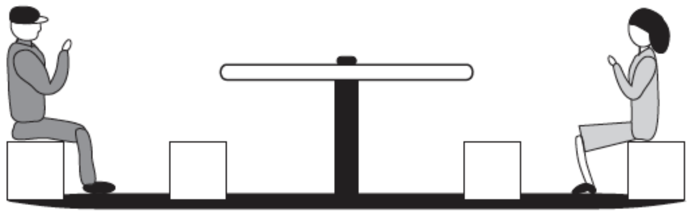
(i) 2.0 ***or*** 0(ms^{-1});
(ii) 1.0 ***or*** 0(ms^{-1});

18b. (i) Outline why Aibhe is accelerating even though she is moving at constant speed. *[6 marks]*

(ii) Draw an arrow on the diagram on page 22 to show the direction in which Aibhe is accelerating.

(iii) Identify the force that is causing Aibhe to move in a circle.

(iv) The diagram below shows a side view of Aibhe and Euan on the merry-go-round.



Explain why Aibhe feels as if her upper body is being “thrown outwards”, away from the centre of the merry-go-round.

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Markscheme

(i) her direction is changing;
hence her velocity is changing;
or
since her direction/velocity is changing;
a resultant/unbalanced/net force must be acting on her (hence she is accelerating);

(ii) arrow from Aibhe towards centre of merry-go-round;
Ignore length of arrow.

(iii) the force of the merry-go-round on Aibhe/her;

(iv) no force is acting on the upper body towards the centre of the circle / no centripetal force acting on the upper body (to maintain circular motion);
upper body (initially) continues to move in a straight line at constant speed/ velocity is tangential to circle;

18c. Euan is rotating on a merry-go-round and drags his foot along the ground to act as a brake. The merry-go-round comes to a stop after 4.0 rotations. The radius of the merry-go-round is 1.5 m. The average frictional force between his foot and the ground is 45 N. Calculate the work done. *[2 marks]*

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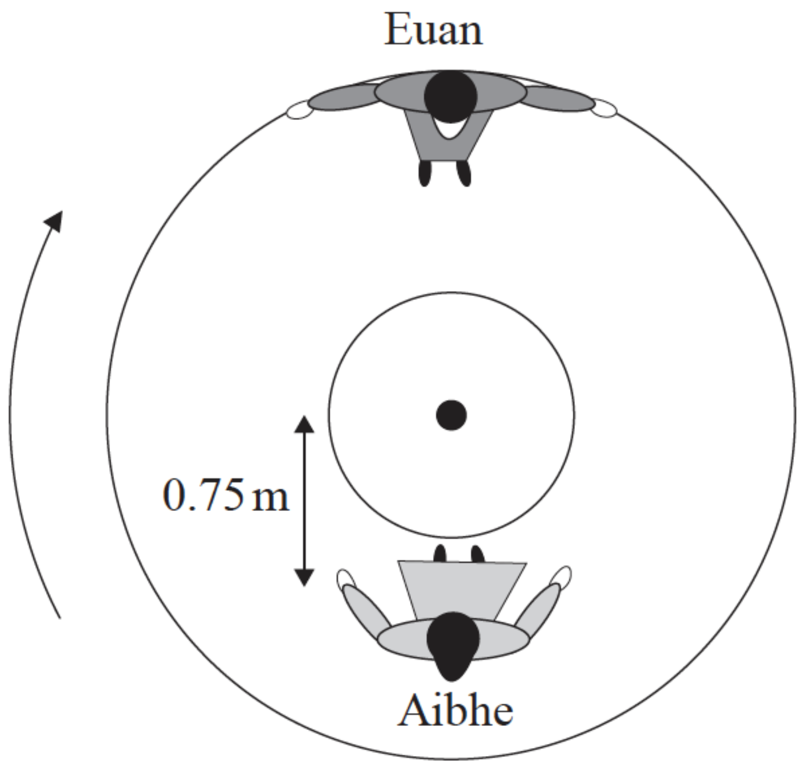
Markscheme

distance travelled by Euan=$4.0 \times 2\pi \times 1.5\,(= 37.70\mathrm{m})$;
$W\,(= F_{av}d = 45 \times 37.70) = 1700\,(\mathrm{J})$;

18d. Aibhe moves so that she is sitting at a distance of 0.75 m from the centre of the merry-go-round, as shown below. *[5 marks]*



Euan pushes the merry-go-round so that he is again moving at 1.0 ms^{-1} relative to the ground.

(i) Determine Aibhe's speed relative to the ground.

(ii) Calculate the magnitude of Aibhe's acceleration.

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Markscheme

(i) Aibhe's period of revolution is the same as before;
from $v = \frac{2\pi r}{T}$, since *r* is halved, *v* is halved;
v=0.5(ms^{-1});
*Award **[3]** for a bald correct answer.*

(ii) $a\left(=\frac{v^2}{r}\right) = \frac{0.5^2}{0.75}$;
a=0.33(ms^{-2});
Allow ECF from (d)(i).
*Award **[2]** for a bald correct answer.*

This question is in **two** parts. **Part 1** is about the motion of a car. **Part 2** is about electricity.

Part 1 Motion of a car

19a. A car accelerates uniformly along a straight horizontal road from an initial speed of $12\ \mathrm{m\,s^{-1}}$ to a final speed of $28\ \mathrm{m\,s^{-1}}$ in a distance of 250 m. The mass of the car is 1200 kg. Determine the rate at which the engine is supplying kinetic energy to the car as it accelerates. *[4 marks]*

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Markscheme

use of a kinematic equation to determine motion time $(= 12.5\ \mathrm{s})$;

change in kinetic energy $= \frac{1}{2} \times 1200 \times \left[28^2 - 12^2\right]\ (= 384\ \mathrm{kJ})$;

rate of change in kinetic energy $= \frac{384000}{12.5}$; } *(allow ECF of 162 from (28 – 12)^2 for this mark)*

31 (kW);

or

use of a kinematic equation to determine motion time $(= 12.5\ \mathrm{s})$;

use of a kinematic equation to determine acceleration $(= 1.28\ \mathrm{ms^{-2}})$;

work done $= \frac{F \times s}{\mathrm{time}} = \frac{1536 \times 250}{12.5}$;

31 (kW);

A driver moves the car in a horizontal circular path of radius 200 m. Each of the four tyres will not grip the road if the frictional force between a tyre and the road becomes less than 1500 N.

19b. (i) Calculate the maximum speed of the car at which it can continue to move in the circular path. Assume that the radius of the path is the same for each tyre. *[6 marks]*

(ii) While the car is travelling around the circle, the people in the car have the sensation that they are being thrown outwards. Outline how Newton's first law of motion accounts for this sensation.

Markscheme

(i) centripetal force must be
$< 6000\ (\mathrm{N})$; *(allow force = 6000 N)*

$v^2 = F \times \frac{r}{m}$;

$31.6\ (\mathrm{m\,s^{-1}})$;

*Allow **[3]** for a bald correct answer.*

*Allow **[2 max]** if* $4\times$ *is omitted, giving 15.8 (m s*$^{-1}$*).*

(ii) statement of Newton's first law;

(hence) without car wall/restraint/friction at seat, the people in the car would move in a straight line/at a tangent to circle;

(hence) seat/seat belt/door exerts centripetal force;

(in frame of reference of the people) straight ahead movement is interpreted as "outwards";