Hong Kong Diploma of Secondary Education Examination

Physics – Compulsory part (必修部分)

Section A – Heat and Gases (熱和氣體)
1. Temperature, Heat and Internal energy (溫度、熱和內能)
2. Transfer Processes (熱轉移過程)
3. Change of State (形態的改變)
4. General Gas Law (普適氣體定律)
5. Kinetic Theory (分子運動論)

Section B – Force and Motion (力和運動)
1. Position and Movement (位置和移動)
2. Newton's Laws (牛頓定律)
3. Moment of Force (力矩)
4. Work, Energy and Power (作功、能量和功率)
5. Momentum (動量)
6. Projectile Motion (拋體運動)
7. Circular Motion (圓周運動)
8. Gravitation (引力)

Section C – Wave Motion (波動)
1. Wave Propagation (波的推進)
2. Wave Phenomena (波動現象)
3. Reflection and Refraction of Light (光的反射及折射)
4. Lenses (透鏡)
5. Wave Nature of Light (光的波動特性)
6. Sound (聲音)

Section D – Electricity and Magnetism (電和磁)
1. Electrostatics (靜電學)
2. Electric Circuits (電路)
3. Domestic Electricity (家居用電)
4. Magnetic Field (磁場)
5. Electromagnetic Induction (電磁感應)
6. Alternating Current (交流電)

Section E – Radioactivity and Nuclear Energy (放射現象和核能)
1. Radiation and Radioactivity (輻射和放射現象)
2. Atomic Model (原子模型)
3. Nuclear Energy (核能)

Physics – Elective part (選修部分)

Elective 1 – Astronomy and Space Science (天文學和航天科學)
1. The universe seen in different scales (不同空間標度下的宇宙面貌)
2. Astronomy through history (天文學的發展史)
3. Orbital motions under gravity (重力下的軌道運動)
4. Stars and the universe (恒星和宇宙)

Elective 2 – Atomic World (原子世界)
1. Rutherford's atomic model (盧瑟福原子模型)
2. Photoelectric effect (光電效應)
3. Bohr's atomic model of hydrogen (玻爾的氫原子模型)
4. Particles or waves (粒子或波)
5. Probing into nano scale (窺探納米世界)

Elective 3 – Energy and Use of Energy (能量和能源的使用)
1. Electricity at home (家居用電)
2. Energy efficiency in building (建築的能源效率)
3. Energy efficiency in transportation (運輸業的能源效率)
4. Non-renewable energy sources (不可再生能源)
5. Renewable energy sources (可再生能源)

Elective 4 – Medical Physics (醫學物理學)
1. Making sense of the eye (眼的感官)
2. Making sense of the ear (耳的感官)
3. Medical imaging using non-ionizing radiation (非電離輻射醫學影像學)
4. Medical imaging using ionizing radiation (電離輻射醫學影像學)

DSE Physics - Section B : M.C. PB - FM7 - M / 01

FM7 : Circular Motion

The following list of formulae may be found useful :

Centripetal acceleration $a = \frac{v^2}{r} = \omega^2 r$

Use the following data wherever necessary :

Acceleration due to gravity $g = 9.81 \text{ m s}^{-2}$ (close to the Earth)

Part A : HKAL examination questions

1. **< HKAL 1980 Paper I - 37 >**

In corners of some racing tracks for motor cars, the tracks are banked at an angle to the horizontal. Which of the following is/are the advantage(s) for this feature ?

(1) To reduce the friction between the car and the track.
(2) To reduce the radius of curvature of the track that a car can travels safely at a given speed.
(3) To increase the component of the weight of the car towards the centre of its path.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

2. **< HKAL 1982 Paper I - 5 >**

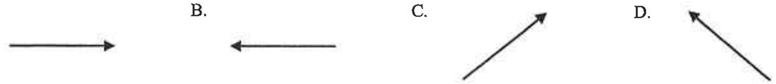
A particle of weight W tied to an inextensible string is swung in a vertical circle. At the topmost point of its path, the tension in the string is T and the centripetal force is F. Which of the following statements is true ?

A. $F = W + T$.
B. $F = W - T$.
C. The net force acting downwards on the stone is $F + T + W$.
D. The net force acting downwards on the stone is $F - T + W$.

3. **< HKAL 1984 Paper I - 4 >**

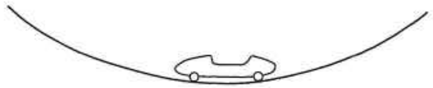
The above diagram represents the front view of a vehicle moving on a level road at a constant speed around a bend of which the centre of curvature is at P. Which of the arrows below best represents the direction of the resultant force exerted by the road on the car ?

A. B. C. D.



4. **< HKAL 1988 Paper I - 6 >**

A toy car of mass m is travelling along a track which is an arc of a vertical circle with radius r. At the bottom of this arc, the speed of the car is v. What is the vertical force exerted on the car by the track at this position ?



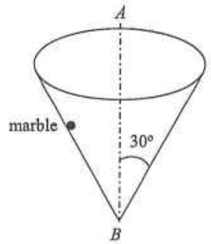
A. $\frac{m v^2}{r}$

B. $m g$

C. $\frac{m v^2}{r} - m g$

D. $\frac{m v^2}{r} + m g$

5. **< HKAL 1989 Paper I - 8 >**



A small marble is rotating on a horizontal circle in a smooth conical container with vertical axis *AB* as shown. The vertical axis makes an angle of 30° with the side of the cone. If the speed of the marble is v and the radius of rotation is r, which of the following relation must be correct ?

A. $v^2 = g\,r \sin 30°$.

B. $v^2 = g\,r \tan 30°$.

C. $v^2 = g\,r / \tan 30°$.

D. $v^2 = g\,r \cos 30°$.

6. **< HKAL 1990 Paper I - 6 >**

A small particle of mass 0.25 kg is attached to an inextensible string, with the other end fixed to the ceiling. When the particle is set to rotate in a horizontal circle, the tension of the string is 3.5 N. The angle between the string and the vertical is

A. 25.5°

B. 32.5°

C. 45.5°

D. 58.5°

7. **< HKAL 1995 Paper IIA - 5 >**

A small particle of mass of 0.05 kg is released from rest at the rim of a smooth semi-spherical bowl of radius 10 cm. Find the force acting on the object by the bowl when it passes the bottom of the bowl.

A. 0.5 N

B. 1.0 N

C. 1.5 N

D. 2.0 N

8. **< HKAL 1995 Paper IIA - 6 >**

An aircraft flies along a horizontal circle of radius 15 km with a constant speed of 175 m s^{-1}. Calculate the angle between its wings and the horizontal.

Take g to be 10 m s^{-2}.

A. 11.5°

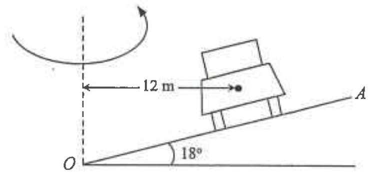
B. 12.5°

C. 13.0°

D. 13.5°

9. **< HKAL 1997 Paper IIA - 4 >**

The figure shows a car moving round a corner with a radius of 12 m on a banked road of inclination 18°. At what speed would there be no friction acting on the car along *OA* ? Take g to be 10 m s^{-2}.



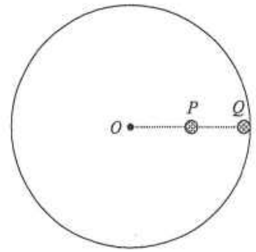
A. 4.8 m s^{-1}

B. 5.4 m s^{-1}

C. 6.2 m s^{-1}

D. 7.6 m s^{-1}

10. **< HKAL 1998 Paper IIA - 7 >**



Two small identical coins *P* and *Q* are placed on a horizontal turntable which is rotating at a constant angular speed about its centre *O*. The radius of *Q* from the centre is twice that of *P*. Which of the following statements is/are correct ?

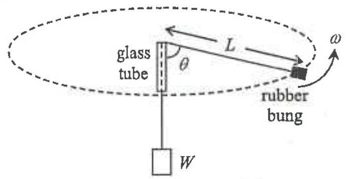
(1) The kinetic energy of *Q* is four times that of *P*.

(2) The friction acting on *Q* is double that acting on *P*.

(3) If the angular speed of the turntable gradually increases, *Q* will slip before *P*.

A. (3) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

11. **< HKAL 2000 Paper IIA - 11 >**



In the experiment of demonstrating centripetal force, a rubber bung is whirled in a horizontal circle. The rubber bung is attached to one end of a string which passes through a glass tube with smooth openings, and attached to a load of weight W hanging at its other end. The rubber bung is set to swirl with angular speed ω while the length of the string beyond the upper opening of the glass tube is L and this portion of the string makes an angle θ with the vertical as shown. Which of the following statements is/are correct ?

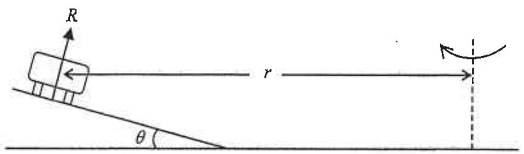
(1) If the length L is kept constant, θ will decrease with ω.

(2) If the angle θ is kept constant, L will increase with ω.

(3) If the weight of the load W increases, θ will increase.

A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

12. **< HKAL 2000 Paper IIA - 8 >**



A vehicle of mass m is moving with speed v on a banked road along a circular path of horizontal radius r. The angle of inclination of the road is θ. If the centripetal force is provided entirely from a component of the normal reaction R from the road, which of the following relations is correct ?

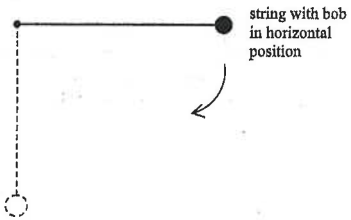
A. $R\cos\theta = mg$

B. $R = mg\cos\theta$

C. $v^2 = \dfrac{gr}{\sin\theta}$

D. $v^2 = \dfrac{gr}{\tan\theta}$

13. **< HKAL 2003 Paper IIA - 7 >**



A small bob is attached to an inextensible string. The string is pulled horizontally and then released from rest with the string taut. Which of the following statements about the tension in the string is NOT correct when the string reaches its vertical position ?

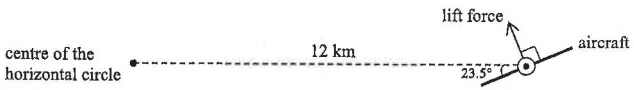
A. The tension equals the weight of the bob in magnitude.

B. The tension attains its greatest value.

C. The tension does not depend on the length of the string.

D. The tension depends on the mass of the bob.

14. **< HKAL 2007 Paper IIA - 4 >**



An aircraft flies with a constant speed in a horizontal circle of radius 12 km. If its wings slant at an angle of 23.5° to the horizontal, find the speed of the aircraft.

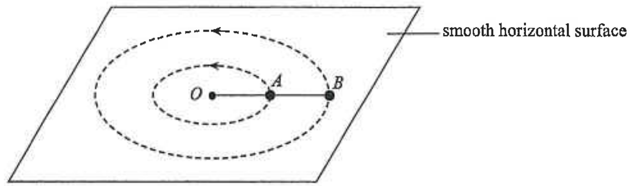
A. 280 m s^{-1}

B. 226 m s^{-1}

C. 140 m s^{-1}

D. 100 m s^{-1}

15. **< HKAL 2010 Paper IIA - 8 >**



Two identical small particles A and B are connected by inextensible threads to a fixed point O as shown. The threads OA and AB are of the same length. Both A and B perform uniform horizontal circular motion about O with the same period. Suppose T_1 and T_2 denote the tensions in the threads OA and AB respectively. Find the ratio $T_1 : T_2$.

A. 3 : 2

B. 2 : 1

C. 3 : 1

D. 4 : 1

16. **< HKAL 2011 Paper IIA - 6 >**

A particle is performing uniform horizontal circular motion about a fixed point on a smooth horizontal plane. Which of the following physical quantities of the particle remain(s) unchanged ?

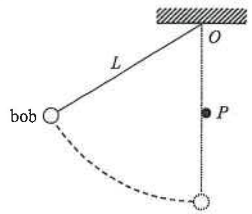
(1) the linear momentum of the particle

(2) the centripetal acceleration of the particle

(3) the kinetic energy of the particle

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

17. **< HKAL 2012 Paper IIA - 9 >**



A heavy bob is suspended from a fixed point O by an inextensible thread of length L. A small peg P is fixed at a distance $\frac{1}{2}L$ vertically below O. The bob is pulled to one side and then released from rest as shown. When the thread just touches the peg, which of the following physical quantities will increase suddenly ?

(1) the linear speed of the bob

(2) the centripetal acceleration of the bob

(3) the tension in the thread

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

Part B : Supplemental exercise

18. The maximum frictional force between the road surface and the wheels of a certain vehicle at a horizontal road is halved when the road is wet. If the maximum safety speed for turning round the bend is 15 m s^{-1} when the road is wet, what is the maximum safety speed when the road is dry ?

A. 21.2 m s^{-1}
B. 22.5 m s^{-1}
C. 26.0 m s^{-1}
D. 30.0 m s^{-1}

19. Which of the following statements is correct for a particle moving in a horizontal circle with constant angular velocity ?

A. The linear momentum is constant but the kinetic energy varies.
B. The linear momentum varies but the kinetic energy is constant.
C. Both the linear momentum and the kinetic energy are constant.
D. Both the linear momentum and the kinetic energy vary.

20. A mass of 2 kg rotates at constant speed in a horizontal circle of radius 5 m and the time for one complete revolution is 3 s. The centripetal force acting on the mass is

A. 2.19 N
B. 4.39 N
C. 43.9 N
D. 109.7 N

21. A particle travels in uniform circular motion with constant radius of curvature. Which of the following statements concerning the motion of the particle is/are correct ?

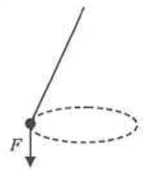
(1) The linear velocity is constant.
(2) The angular velocity is constant.
(3) The centripetal acceleration is constant.

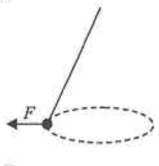
A. (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

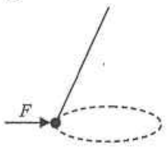
22. An aircraft is moving in a horizontal plane at a constant speed of 650 m s^{-1}. The radius of its circular path is 80 km. What is the ratio of the centripetal force to the weight of the aircraft ?

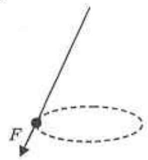
A. 0.019
B. 0.54
C. 1.85
D. 52

23. A particle is attached to an inextensible string and is set into circular motion in a horizontal plane. Which of the following diagrams correctly shows the direction of the resultant force F acting on the particle ?

A.


B.


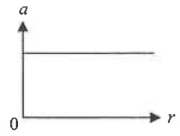
C.


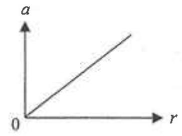
D.


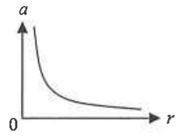
24. The minute hand of a large clock is 1.2 m long. What is its average angular speed ?

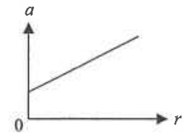
A. 0.87×10^{-3} rad s^{-1}
B. 1.45×10^{-3} rad s^{-1}
C. 1.75×10^{-3} rad s^{-1}
D. 2.09×10^{-3} rad s^{-1}

25. A record on a turntable is rotating at a constant period. Which graph shows correctly the relation between the acceleration a of particles fixed on the surface of the record and their distance r from the centre of rotation ?

A.


B.


C.


D.


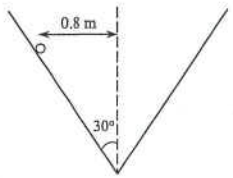
26. An aircraft is travelling at constant speed in a horizontal circle with centre O. The diagrams below show the tail-view of the aircraft, the dotted line representing the line of the wings and the circle representing the centre of gravity of the aircraft. Which one of the diagrams correctly shows the forces acting on the aircraft ?

A.


B.


C.


D.

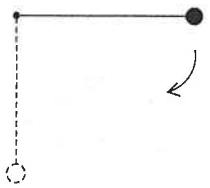

27.


A small ball bearing of mass 0.2 kg is whirling in a horizontal circle with radius 0.8 m inside a smooth inverted cone. What is the linear speed of the ball bearing ?

A. 2.1 m s^{-1}
B. 3.0 m s^{-1}
C. 3.7 m s^{-1}
D. 4.0 m s^{-1}

Part C : HKDSE examination questions

28. **< HKDSE Sample Paper IA - 10 >**



A simple pendulum is pulled horizontally and then released from rest with the string taut. Which of the following statements about the tension in the string is **not correct** when the pendulum reaches its vertical position ?

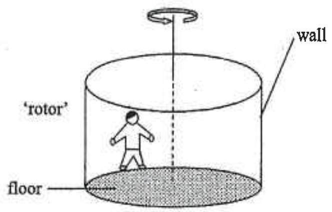
A. The tension equals the weight of the pendulum bob in magnitude.

B. The tension attains its greatest value.

C. The tension does not depend on the length of the pendulum.

D. The tension depends on the mass of the pendulum bob.

29. **< HKDSE Practice Paper IA - 12 >**



A man is rotating with constant speed inside a cylindrical 'rotor' and the he remains pressed against the wall. The floor of the 'rotor' is smooth. Which of the following forces provides the centripetal force for the man ?

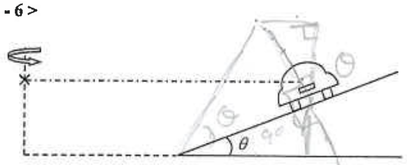
A. the weight of the man

B. the frictional force from the wall

C. the normal reaction from the wall

D. the supporting force from the floor.

30. **< HKDSE 2015 Paper IA - 6 >**



The figure shows the rear view of a car of mass m which travels along a circular road banked with an angle θ to the horizontal. The car moves at a certain speed such that it experiences no frictional force along the inclined surface. Which of the following represents the centripetal force on the car ?

A. $mg\sin\theta$

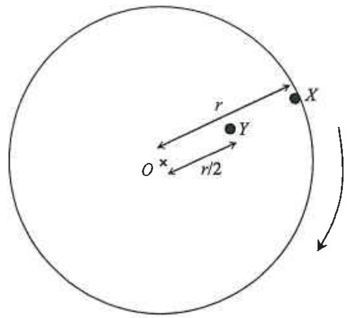
B. $mg\sin\theta\cos\theta$

C. $mg\cos\theta / \sin\theta$

D. $mg\sin\theta / \cos\theta$

31. **< HKDSE 2016 Paper IA - 13 >**

Particles X and Y are fixed at distances r and $r/2$ respectively from the centre O of a horizontal circular platform which is rotating uniformly as shown.



TOP VIEW

The ratio of the acceleration of X to that of Y is

A. 1 : 2

B. 2 : 1

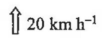
C. 1 : 4

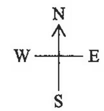
D. 4 : 1

32. **< HKDSE 2016 Paper IA - 5 >**

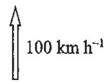
A car travelling at 80 km h^{-1} due east changes direction and travels at 60 km h^{-1} due north. Which diagram represents the change in velocity of the car ?

A.

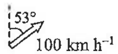




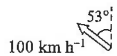
B.



C.



D.



3. (b) (iv) v decreases [1]

θ decreases as v decreases, i.e. $v\downarrow \Rightarrow \theta\downarrow$, from (3): $v^2 = gL\cdot\tan\theta\cdot\sin\theta$ [1]

From (2), $T = \dfrac{mg}{\cos\theta}$ so T decreases, i.e. $\theta\downarrow \Rightarrow \cos\theta\uparrow \Rightarrow T\downarrow$ [1]

4. (a)

< Weight drawn, labelled with W or mg > [1]
< Tension drawn, labelled with T > [1]
[Deduct 1 mark if extra force or centripetal force is drawn]

(b) Resolve the tension T into two components.

$T\sin\theta = mL\sin\theta\,\omega^2$ [1]

$T\cos\theta = mg$ [1]

$\therefore \dfrac{mg}{\cos\theta} = mL\omega^2 \qquad \therefore \omega^2 = \dfrac{g}{L\cos\theta}$ [1]

Period $= \dfrac{2\pi}{\omega} = 2\pi\sqrt{\dfrac{L\cos\theta}{g}}$ [1]

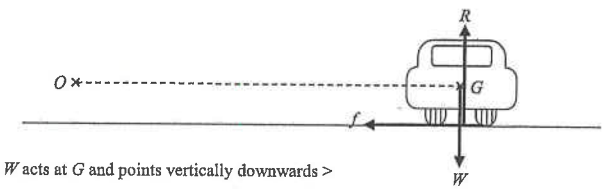
(c) Period $= 2\pi\times\sqrt{\dfrac{(0.8)\cos 25^\circ}{(9.81)}}$ [1]

$= 1.71$ s [1]

(d) (i) If the angle θ is increased, $\cos\theta$ would decrease, [1]
thus the period would decrease. [1]

(ii) If the angle θ is increased, by $T\cos\theta = mg$ [1]
the tension would increase. [1]

5. (a)



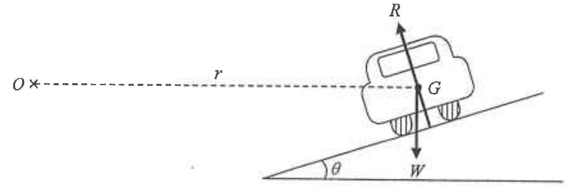
< weight W acts at G and points vertically downwards > [1]
< normal reaction R points vertically upwards > [1]
< friction f acts on the wheels and points leftwards > [1]
[if the force towards O is labelled as centripetal force, no mark should be given]
[if centrifugal force is drawn, deduct 1 mark]

5. (b) $f = \dfrac{mv^2}{r}$

$= \dfrac{(1800)(15)^2}{(75)}$ [1]

$= 5400$ N [1]

(c) (i)



< normal reaction R acts on the car perpendicular to the inclined plane > [1]
< weight W acts at G vertically downwards > [1]
[if friction is drawn, deduct 1 mark]
[if centripetal force is drawn, deduct 1 mark]

(ii) The centripetal force is provided by the horizontal component of the normal reaction. [1]

(iii) $R\sin\theta = \dfrac{mv^2}{r}$ [1]

$R\cos\theta = mg$ [1]

$\therefore \tan\theta = \dfrac{v^2}{gr}$ [1]

(iv) ① To give greater speed without skidding. [1]

② A smaller radius of bending road can be designed for vehicles without skidding. [1]

6. (a) $P\cos 36^\circ = (4.5\times10^5)(9.81)$ [1]

$\therefore P = 5.46\times10^6$ N [1]

(b) Centripetal force $= P\sin\theta$

$= (5.46\times10^6)\sin 36^\circ$ [1]

$= 3.21\times10^6$ N [1]

(c) $F = ma$

$\therefore (3.21\times10^6) = (4.5\times10^5)\,a$ [1]

$\therefore a = 7.13$ m s^{-2} [1]

The direction of the acceleration is towards the centre O. [1]

Question Solution

1. (a) F_A : friction [1]

F_B : normal reaction [1]

(b) $F_A = m g$ [1]

maximum $F_A = 0.4 F_B$

$\therefore\ m g = 0.4 \times m r \omega^2$ [1]

$\therefore\ (9.81) = 0.4 \times (3.2)\ \omega^2$

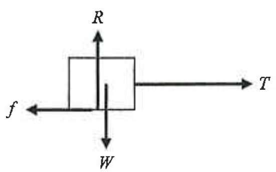
$\therefore\ \omega = 2.77 \text{ rad s}^{-1}$ [1]

(c) The result is unchanged. [1]

As the centripetal force is proportional to maximum F_A which is equal to the weight $m g$,

the minimum angular speed is independent of the mass m. [1]

2. (a) (i)



< Any two forces drawn correctly > [1]

< All four forces drawn correctly > [1]

(ii) Applied horizontal force $= T - f_{max}$ [1]

$= 10 - 3 = 7 \text{ N}$ [1]

(b) (i) Minimum angular speed occurs when the maximum friction directs away from the centre, so that the centripetal force is the minimum.

$\therefore\ T - f_{max} = m r \omega_1^2$ [1]

$\therefore\ (10) - (3) = (0.5) \times (0.1)\ \omega_1^2$

$\therefore\ \omega_1 = 11.8 \text{ rad s}^{-1}$ [1]

(ii) Maximum angular speed occurs when the maximum friction directs towards the centre, so that the centripetal force is the maximum.

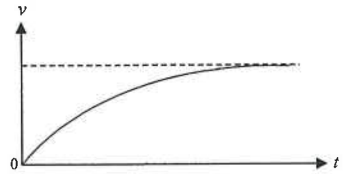
$\therefore\ T + f_{max} = m r \omega_2^2$

$\therefore\ (10) + (3) = (0.5) \times (0.1)\ \omega_2^2$ [1]

$\therefore\ \omega_2 = 16.1 \text{ rad s}^{-1}$ [1]

(c) The tension is unchanged. [1]

3. (a)



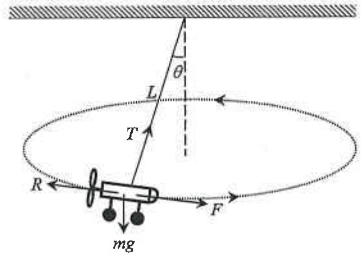
[1]

As the toy increases its velocity, the air resistance on the toy increases. [1]

The net force and thus the acceleration of the toy decrease. [1]

Finally, when the air resistance equals the propelling force of the fan, the toy reaches its final terminal velocity. [1]

(b) (i)



R is air resistance [1]

F is propelling force [1]

mg is weight and T is tension [1]

[Deduct 1 mark if "centripetal force" is drawn]

[Deduct 1 mark if the forces are only labelled without naming]

(ii) $T \sin\theta = \dfrac{m v^2}{L \sin\theta}$ $\quad (r = L \sin\theta)$

$\therefore\ T \sin^2\theta = \dfrac{m v^2}{L}$ ..... (1) [1]

$T \cos\theta = m g$ ..... (2) [1]

(iii) $\dfrac{(1)}{(2)}$: $\dfrac{\sin^2\theta}{\cos\theta} = \dfrac{v^2}{gL}$ ..... (3)

$\therefore\ \dfrac{1 - \cos^2\theta}{\cos\theta} = \dfrac{(2)^2}{(10)(0.8)}$ [1]

$\therefore\ 2 - 2\cos^2\theta = \cos\theta$

$\therefore\ 2\cos^2\theta + \cos\theta - 2 = 0$

$\therefore\ \cos\theta = 0.7808$ $\qquad \therefore\ \theta = 38.7°$ [1]

By (2) : $T = 1.28 \text{ N}$ [1]

10. <HKDSE 2019 Paper-IB-4>

(ii) Indicate on Figure 4.1 the centripetal force F_C required for the motion of the bob. Find F_C. (3 marks)

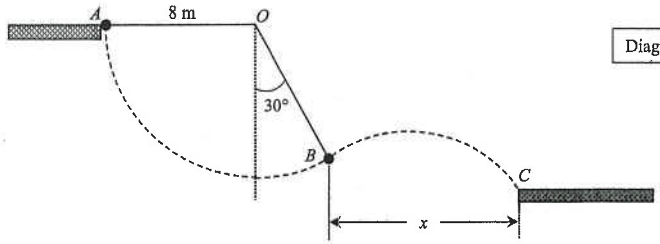
(iii) Explain whether the magnitude of the tension in the string is greater than, equal to or smaller than the centripetal force F_C found in (a)(ii). (2 marks)

(b) The moon is orbiting around the Earth uniformly in a circular path under the influence of the Earth's gravitational attraction.

(i) Explain why the speed of the moon remains unchanged although it is acted upon by gravitational force. (2 marks)

(ii) A student claimed that as the moon is much less massive than the Earth, it exerts negligible force on the Earth. Comment on the student's claim. (2 marks)

8. < HKDSE 2015 Paper IB - 3 >



The above Figure shows two horizontal platforms with end points A and C. An acrobat tries to swing from A to C by using a light rope of 8 m long and with one end fixed at point O, which is at the same level as A. He leaves A by holding the end of the rope and then releases it when reaching point B at which the angle between the rope and the vertical is 30°. The acrobat can be treated as a point mass and the rope remains taut and not extended throughout the motion. Neglect air resistance. ($g = 9.81$ m s^{-2})

(a) Mark on the above Figure the velocity v_B of the acrobat at B. If the speed of the acrobat when leaving A is zero, find the magnitude of v_B. (3 marks)

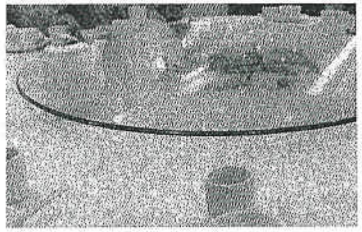
(b) (i) It takes 1.25 s for the acrobat to reach C after releasing the rope at B. By considering his horizontal motion, find the horizontal separation x between B and C. (2 marks)

(ii) Calculate the vertical distance of C below B. (3 marks)

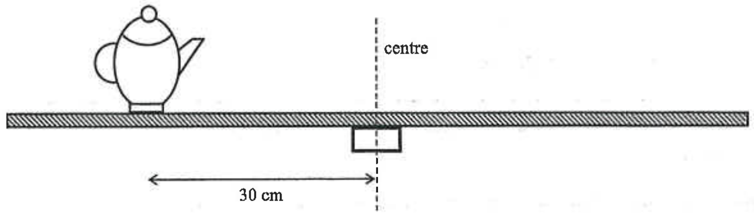
(c) Before reaching the lower platform, is there any change to the acrobat's mechanical energy among the points A, B and C? (1 mark)

9. < HKDSE 2017 Paper IB - 5 >

The photo shows a turntable commonly used in restaurants.



A teapot of mass 1 kg is put 30 cm from the centre of a horizontal turntable, and the Figure below shows the side view. When the turntable is rotating, the teapot remains at the same position on the turntable.

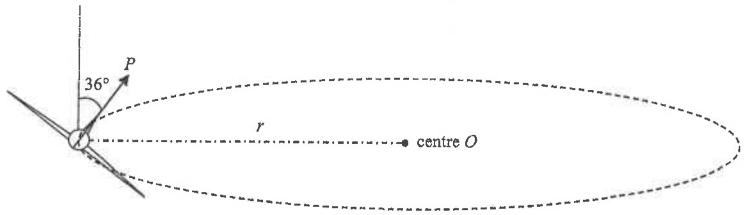


(a) On the above Figure, draw and label all the forces acting on the teapot when the turntable is rotating. (2 marks)

(b) Taking the teapot as a point mass, estimate the net force acting on the teapot when the turntable is rotating at a rate of 0.5 revolutions per second. (3 marks)

(c) The turntable is suddenly stopped and the teapot slips. The turntable is rotating at a rate of 0.5 revolutions per second just before it stops, and the frictional force acting on the teapot is 10 N when it is slipping. Determine the distance travelled by the teapot after the turntable stops. (3 marks)

6. An aircraft flies with its wings tilted 36° in order to fly in a horizontal circle of radius r as shown below. The aircraft has a mass of 4.5×10^5 kg and it moves with a constant speed of 240 m s^{-1}. The figure shows that there is a lift force P acting on the aircraft.



(a) Calculate the lift force P shown in the figure. (2 marks)

(b) Determine the centripetal force acting on the aircraft. (2 marks)

(c) Find the acceleration of the aircraft. What is the direction of the acceleration ? (3 marks)

(d) Calculate the radius r of the circular path of the aircraft's flight. (2 marks)

(e) Suppose the aircraft moves with the same speed but tilts with a greater angle. What are the effects on the following :

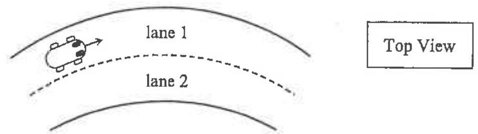
(i) the lift force P ; (1 mark)

(ii) the centripetal acceleration ; (1 mark)

(iii) the radius of the circular path r. (1 mark)

Part C : HKDSE examination questions

7. **< HKDSE 2012 Paper IB - 3 >**



The Figure above shows the top view of a horizontal road with two circular lanes. A car of mass 1200 kg moves with constant speed in lane 1 of radius 45 m.

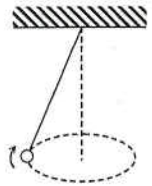
(a) (i) Name the force that provides the centripetal force for the car. If the maximum value of this force is 8000 N, calculate the highest speed of the car such that it can keep in lane 1. (3 marks)

(ii) Suppose the car takes lane 2 instead of lane 1 and the maximum value of the force providing the centripetal force is still 8000 N. Would the car's highest speed in lane 2 be smaller than, larger than or the same as that found in (a) (i) ? Explain. (2 marks)

(b) Explain why the chance of skidding would increase if there are oil patches on the road surface in the above Figure. (2 marks)

Part B : Supplemental exercise

4. A bob is attached to a string and made to revolve in a horizontal circle as shown.



(a) Draw and label the forces acting on the bob at the instant shown. (2 marks)

(b) If the length of the string is L and the angle that the string made with the vertical is θ, derive an expression for the period of the circular motion. (Neglect air resistance.) (4 marks)

(c) Calculate the period of the circular motion if the length of the string is 0.8 m and the string makes an angle of 25° during the circular motion. (2 marks)

(d) Explain and describe the effects on

(i) the period of revolution ; and

(ii) the tension of the string,

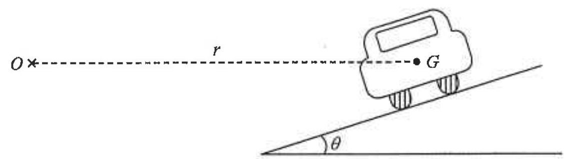
if the angle made with the vertical is increased during the revolution. (4 marks)

5. The figure shows the rear view of a car with mass 1800 kg which turns round a horizontal circular road with a uniform speed of 15 m s^{-1}. G is the centre of gravity of the car and O is the centre of its circular motion. The radius of the circular road is 75 m. Neglect air resistance.

(a) Let R be the normal reaction on the car, and let f be the friction on the wheels, draw all the forces acting on the car in the above figure. (3 marks)

(b) Calculate the magnitude of friction acting on the car. (2 marks)

(c) Now the road is banked with an angle θ to the horizontal as shown. The ideal banking angle is designed so that there is no friction acting on the car.



(i) Draw the forces acting on the car in the figure. (2 marks)

(ii) State which force provides the centripetal force for the car to travel in circular motion. (1 mark)

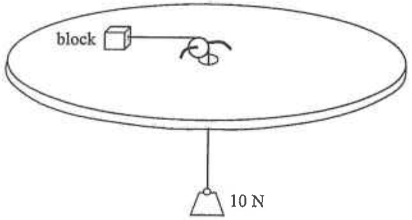
(iii) Derive an expression for the ideal banking angle in terms of v and r. (3 marks)

(iv) Give **TWO** advantages of banking at a bend in highways. (2 marks)

2. < **HKAL 2003 Paper I - 1** >

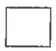
A small block of mass 0.5 kg is placed at 10 cm from the centre of a horizontal turntable. The block is connected to one end of a light inextensible string which passes over a small smooth pulley fixed at the centre of the turntable, as shown in the below figure. The string runs through a hole at the centre of the turntable and a weight of 10 N is suspended at its other end. The maximum friction between the block and the turntable is 3 N.

(Note : The axle of the turntable is not shown in the diagram.)



(a) Suppose the turntable is stationary.

(i) Draw a diagram to show all the force(s) acting on the block. (2 marks)



(ii) Find the minimum external force applied to the block that needs to keep the block stationary. (2 marks)

(b) Suppose the turntable is rotating with a certain angular speed about its centre.

(i) Calculate the minimum angular speed ω_1 of the turntable such that the block can remain at its original position without slipping. (2 marks)

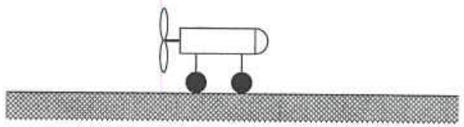
(ii) Calculate the maximum angular speed ω_2 of the turntable such that the block can remain at its original position without slipping. (2 marks)

(c) When the angular speed of the turntable is increased gradually from ω_1 to ω_2 and the block does not slip. State the change, if any, of the tension in the string. (1 mark)

3. < **HKAL 2008 Paper I - 5** >

In Figure 1, a toy is placed on a smooth horizontal surface. It is equipped with a fan powered by a battery. When the fan is switched on, the toy starts moving to the right and it finally reaches a constant velocity.

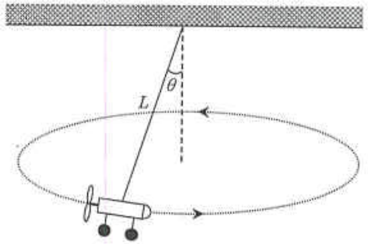
Figure 1



(a) With the aid of a velocity-time graph, explain the motion of the toy after the fan is switched on. (4 marks)

(b) The toy of mass m is now attached to a fixed point on the ceiling by a light string of length L. It is set into a uniform horizontal circular motion as shown in Figure 2. The string makes an angle θ to the vertical when the velocity of the toy is v. Take g to be 10 m s^{-2}.

Figure 2



(i) Draw and name all the force(s) acting on the toy in Figure 2. (3 marks)

(ii) Write down **TWO** equations for the vertical and horizontal components of forces on the toy. (2 marks)

(iii) If m = 0.1 kg, L = 0.8 m and v = 2 m s^{-1}, show that the angle θ satisfy the equation : $2\cos^2\theta + \cos\theta - 2 = 0$
Hence calculate the values of θ and tension T. (3 marks)

(iv) If the output voltage of the battery inside the toy drops slightly, describe and explain its subsequent motion in terms of v, θ and T. (3 marks)

The following list of formulae may be found useful :

Centripetal acceleration $a = \frac{v^2}{r} = \omega^2 r$

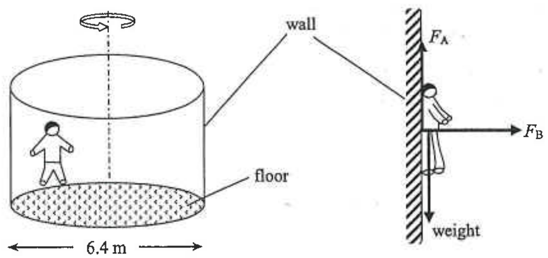
Use the following data wherever necessary :

Acceleration due to gravity $g = 9.81 \text{ m s}^{-2}$ (close to the Earth)

Part A : HKAL examination questions

1. < HKAL 2001 Paper I - 1 >

The figure below shows a man of mass 80 kg standing against the wall of a cylindrical compartment called a 'rotor'. The level of the rotor's floor can be adjusted. The diameter of the rotor is 6.4 m.



The rotor is spun at a certain angular speed about its central vertical axis. At this angular speed, the man inside remains 'pinned' against the wall even if the floor of the rotor is pulled downwards.

(a) Name the forces F_A and F_B acting on the man. (2 marks)

(b) It is known that the maximum value of F_A equals 0.4 F_B. Find the minimum angular speed, in rad s^{-1}, of the rotor that needed to keep the man 'pinned' against the wall. (3 marks)

(c) If the mass of the man is greater than 80 kg, would the result in (b) increase, decrease or remain unchanged ? Explain briefly. (2 marks)

19. B

Since the direction of the velocity is always changing,
the direction of the linear momentum varies, thus linear momentum varies

As the magnitude of the velocity is constant, the kinetic energy is constant as kinetic energy is a scalar without direction.

20. C

$F = m r \omega^2$

$= m r (\frac{2\pi}{T})^2 = (2)(5)(\frac{2\pi}{3})^2 = 43.9 \text{ N}$

21. A

× (1) As the direction of the velocity is always changing, the linear velocity varies.

✓ (2) The direction of angular velocity is constant (either always in clockwise or in anticlockwise direction), and the magnitude of angular velocity ($\omega = v / r$) is also constant, thus angular velocity is constant.

× (3) The direction of the centripetal acceleration is always towards the centre, thus its direction is always changing, therefore, centripetal acceleration varies.

22. B

$\frac{F}{W} = \frac{m v^2 / r}{m g} = \frac{v^2}{g r} = \frac{(650)^2}{(9.81)(80 \times 10^3)} = 0.54$

23. C

The resultant force is the centripetal force which must be directed towards the centre of the circular path.

24. C

The period of the minute hand of a clock is 60 minutes for one revolution.

Angular speed :

$\omega = \frac{2\pi}{T} = \frac{2\pi}{(60 \times 60)} = 1.75 \times 10^{-3} \text{ rad s}^{-1}$

25. B

Angular speed : $\omega = 2\pi / T$, as period is constant, ω is constant.

By $a = r\omega^2$, as ω for the particle on the record is the same $\therefore v \propto r$

A graph of v against r should be a straight line through the origin.

26. B

There are two forces acting on the aircraft :

① the weight which is vertically downwards

② the lift force which is perpendicular to the wings

27. C

There is two forces acting on the ball bearing : the weight mg and the normal reaction R.

Vertically, $R \sin 30° = m g$

Horizontally, $R \cos 30° = \frac{m v^2}{r}$

$\therefore \tan 30° = \frac{g r}{v^2}$

$\therefore \tan 30° = \frac{(9.81)(0.8)}{v^2}$ $\therefore v = 3.7 \text{ m s}^{-1}$

28. A

× A. At the lowest point, $T - W = \frac{mv^2}{r}$. Thus the tension should be greater than the weight.

✓ B. The tension is the greatest at the lowest point since it supports the weight and provide the greatest centripetal force as the speed of bob is maximum.

✓ C. During the swing from horizontal position to vertical position, $m g r = \frac{1}{2} m v^2$ $\therefore v^2 = 2 g r$

At the vertical position, tension of the string : $T = W + \frac{mv^2}{r} = m g + \frac{m(2gr)}{r} = 3 mg$

The tension is thus not affected by the length of the pendulum.

✓ D. The tension is 3 mg which depends on the mass of the bob m.

29. C

The centripetal force must be directed towards the centre.

This force should be provided by the normal reaction from the wall on the man.

The normal reaction by the wall is horizontally acting on the back of the man away from the wall towards the centre.

30. D

There is two forces acting on the car : weight mg and normal reaction R.

Since the vertical forces are balanced :

$R \cos\theta = mg$ $\therefore R = \frac{mg}{\cos\theta}$

The horizontal component of the normal reaction provides the centripetal force.

Thus, the centripetal force on the car :

$F = R \sin\theta = \frac{mg}{\cos\theta} \times \sin\theta = \frac{mg \sin\theta}{\cos\theta}$

31. B

Since the two particles are moving in the same rotating platform, their angular velocity ω must be the same .

Centripetal acceleration : $a = r\omega^2$

Since ω is the same, thus $a \propto r$

$\therefore a_X : a_Y = r_X : r_Y = 2 : 1$

9. C

If no friction is required, the horizontal component of the normal reaction force gives centripetal force.

Horizontally : $R\sin 18° = \frac{mv^2}{r}$

Vertically : $R\cos 18° = mg$

$\therefore \tan 18° = \frac{v^2}{(10)(12)}$ $\therefore v = 6.2 \text{ m s}^{-1}$

10. D

Since coin P and coin Q are rotating on the same disc, they must have the same angular speed ω (also same period).

✓ (1) By $v = r\omega$, $v \propto r$, thus speed of Q is two times that of P.
By $KE = \frac{1}{2}mv^2$, kinetic energy of Q is four times that of P.

✓ (2) By $f = mr\omega^2$, $f \propto r$, thus friction acting on Q is double that acting on P.

✓ (3) If the angular speed gradually increases, the friction that provides the centripetal force must increase.
As the friction of Q is greater, the friction on Q would reach the maximum friction first, thus B slips first.

11. C

× (1) By $T\sin\theta = m(L\sin\theta)\omega^2$ If L is kept constant, $\omega\uparrow$, $T\uparrow$ (T can be increased by increasing W)
By $T\cos\theta = mg$ When $T\uparrow$, $\cos\theta\downarrow$ $\therefore \theta\uparrow$ $\therefore \theta$ should be increased with ω.

× (2) By $T\cos\theta = mg$, if θ is constant, then T is also constant.
By $T\sin\theta = mL\sin\theta\,\omega^2$ $\therefore \omega\uparrow \Rightarrow L\downarrow$ $\therefore L$ will decrease with ω.

✓ (3) By $T = W$ $\therefore W\uparrow \Rightarrow T\uparrow$
By $T\cos\theta = mg$ $\therefore T\uparrow \Rightarrow \cos\theta\downarrow \Rightarrow \theta\uparrow$

12. A

Consider vertical component : $R\cos\theta = mg$ ... (1) $\therefore$ A is correct but B is incorrect.

Consider horizontal component : $R\sin\theta = \frac{mv^2}{r}$ ... (2)

Combine (1) and (2) : $v^2 = gr\tan\theta$ $\therefore$ C and D are incorrect.

13. A

× A. At the lowest point, $T - W = \frac{mv^2}{r}$. Thus the tension should be greater than the weight of the bob.

✓ B. The tension is the greatest at the lowest point
since it supports the weight bob and provides the greatest centripetal force.

✓ C. During the swing from horizontal position to vertical position, $mgr = \frac{1}{2}mv^2$ $\therefore v^2 = 2gr$
At the vertical position, tension of the string : $T = W + \frac{mv^2}{r} = mg + \frac{m(2gr)}{r} = 3\,mg$
Thus, the tension is not affected by the length of the string.

✓ D. The tension is 3 mg at the vertical position, thus it depends on the mass of the bob m.

14. B

By $\tan\theta = \frac{v^2}{g \cdot r}$

$\therefore \tan 23.5° = \frac{v^2}{(9.81)(12\times10^3)}$

$\therefore v = 226 \text{ m s}^{-1}$

15. A

Since the two particles have the same period, they must have the same angular speed ω.

Let the mass of each particle be m, and let OA be r and OB be $2r$.

Consider A : $T_1 - T_2 = mr\omega^2$

Consider B : $T_2 = m(2r)\omega^2$

Combine the two equations :

$\therefore 2(T_1 - T_2) = T_2$

$\therefore T_1 : T_2 = 3 : 2$

16. B

× (1) Momentum is a vector. As the direction of velocity changes, direction of momentum also changes.

× (2) Centripetal acceleration is a vector. Its direction is always towards the centre.
Thus the direction of centripetal acceleration is always changing.

✓ (3) Kinetic energy is a scalar. For uniform circular motion, the speed is constant, thus KE is constant.

17. D

As the thread just touches the peg, the radius of the circular motion suddenly becomes halved.

× (1) The speed would not change as the kinetic energy does not change when the thread touches the peg.

✓ (2) Centripetal acceleration : $a = \frac{v^2}{r}$.
As r is halved, a is doubled, thus the acceleration will increase.

✓ (3) Tension : $T - mg = \frac{mv^2}{r}$. As r is halved, T will increase.

18. A

In a horizontal road, friction is the only force that can provide the centripetal force.

$\therefore f = \frac{mv^2}{r}$ $\therefore f \propto v^2$

$\therefore \frac{f_w}{f_d} = (\frac{v_w}{v_d})^2$

$\therefore \frac{1}{2} = (\frac{15}{v_d})^2$

$\therefore v_d = 21.2 \text{ m s}^{-1}$

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

M.C. Answers

1. C	11. C	21. A	31. B
2. A	12. A	22. B	32. D
3. D	13. A	23. C	**33. D**
4. D	14. B	24. C	34. A
5. C	15. A	25. B	
6. C	16. B	26. B	
7. C	17. D	27. C	
8. A	18. A	28. A	
9. C	19. B	29. C	
10. D	20. C	30. D	

M.C. Solution

1 C

✓ (1) Horizontal component of the normal reaction $R \sin \theta$ can be used to provide the centripetal force, thus the need of frictional force for providing the centripetal force is reduced.

✓ (2) The horizontal component of the normal reaction helps to provide the centripetal force, thus the centripetal acceleration can be increased.
As $a = v^2 / r$,
the increase of centripetal acceleration a can give a smaller radius of curvature r of a circular path.

× (3) As the direction of the weight is vertical, it can never give a horizontal component to provide the centripetal acceleration which is horizontal.

2. A

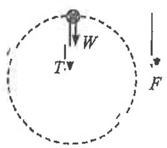
There are only two forces acting on the stone:

① the weight W

② the tension T

As centripetal force F is the net force,

$\therefore \quad F = W + T$

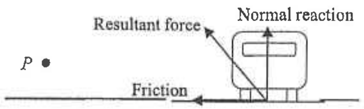


3. D

Friction exerted by the road provides the centripetal force, thus its direction is towards the centre P to the left.

Normal reaction exerted by the road acts to balance the weight.

The resultant of these two forces exerted by the road is shown.



4. D

The vertical force exerted on the car by the track is the normal reaction R.

The centripetal force is the net force towards the centre, thus the centripetal force is $R - mg$.

$\therefore \quad R - mg = \dfrac{m v^2}{r}$

$\therefore \quad R = m g + \dfrac{m v^2}{r}$

5. C

Consider vertical motion, $R \sin 30° = mg$ ... (1)

Consider horizontal motion, $R \cos 30° = \dfrac{mv^2}{r}$ ... (2)

$\therefore \quad \tan 30° = \dfrac{g r}{v^2}$ $\qquad \therefore \quad v^2 = \dfrac{g r}{\tan 30°}$

6. C

When the mass is set to rotate, it is a conical pendulum.

$T \cos \theta = m g$

$\therefore \quad (3.5) \cos \theta = (0.25)(9.81)$

$\therefore \quad \theta = 45.5°$

7. C

Consider the motion from the rim to the bottom :

$m g h = \frac{1}{2} m v^2$

$\therefore \quad m (9.81)(0.10) = \frac{1}{2} m v^2 \qquad \therefore \quad v = 1.40 \text{ m s}^{-1}$

At the bottom, the resultant of the normal reaction and the weight gives the centripetal force.

$R - mg = \dfrac{m v^2}{r}$

$\therefore \quad R - (0.05)(9.81) = \dfrac{(0.05)(1.4)^2}{(0.10)} \qquad \therefore \quad R = 1.47 \text{ N} \approx 1.5 \text{ N}$

8. A

The lift force L on the aircraft should be resolved into two components :

vertical component $= L \cos \theta$

horizontal component $= L \sin \theta$

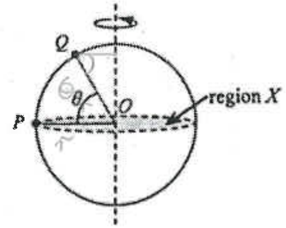
$\therefore \quad L \sin \theta = \dfrac{m v^2}{r}$ and $L \cos \theta = m g$

$\therefore \quad \tan \theta = \dfrac{v^2}{g r} = \dfrac{(175)^2}{(10)(15 \times 10^3)} \qquad \therefore \quad \theta = 11.5°$

33.<HKDSE 2020 Paper IA-8>

34. <HKDSE 2020 Paper IA-9>

Particles P and Q are fixed on the surface of a sphere rotating about a vertical axis passing through the centre O of the sphere as shown. The horizontal shaded region X divides the sphere into two halves. P is at the edge of region X while Q is at an angle of elevation θ above region X.



Find the ratio of the centripetal acceleration of P to that of Q.

A. $1 : \cos\theta$
B. $1 : \sin\theta$
C. $\cos\theta : 1$
D. $\sin\theta : 1$

6. (d) $a = \frac{v^2}{r}$

$\therefore$ $(7.13) = \frac{(240)^2}{r}$ [1]

$\therefore$ r = 8080 m [1]

(e) (i) increase [1]

(ii) increase [1]

(iii) decrease [1]

7. (a) (i) Friction provides the centripetal force for the car. [1]

$f = \frac{m v^2}{r}$ [1]

$\therefore$ $(8000) = \frac{(1200) v^2}{(45)}$

$\therefore$ v = 17.3 m s^{-1} [1]

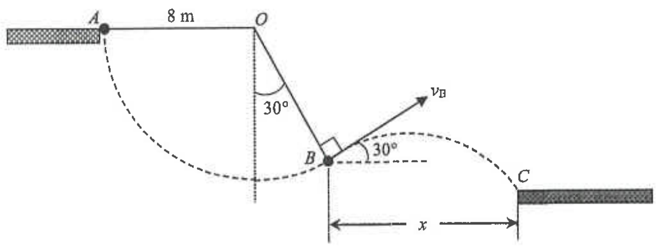
(ii) The car's highest speed in lane 2 would be smaller. [1]

For the same f, $v^2 \propto r$, as the radius r of lane 2 is smaller, the speed v is smaller. [1]

(b) If there are oil patches, the maximum friction acting on the car by the road would decrease. [1]

Thus the highest speed without skidding would decrease. [1]

8. (a)



< direction of v_B marked perpendicularly to the rope OB > [1]

By Conservation of energy :

$\therefore$ $m g h = \frac{1}{2} m v^2$

$\therefore$ $(9.81) \times (8 \cos 30°) = \frac{1}{2} v_B^2$ [1]

$\therefore$ v_B = 11.7 m s^{-1} [1]

8. (b) (i) $x = u_x t$

$= (11.7 \cos 30°) \times (1.25)$ [1]

= 12.7 m < accept 12.6 m to 12.8 m > [1]

(ii) $y = u_y t + \frac{1}{2} a_y t^2$ [1]

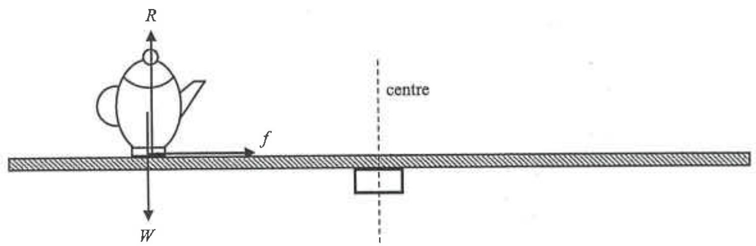
$= (11.7 \sin 30°) \times (1.25) + \frac{1}{2}(-9.81) \times (1.25)^2$ [1]

= – 0.352 m [1]

C is at 0.352 m below B. < accept 0.352 m to 0.414 m >

(c) No ! The mechanical energy is unchanged. [1]

9. (a)



< Weight W and normal reaction R correctly drawn and labelled > [1]

< Friction f correctly drawn and labelled > [1]

[W can be labelled with mg or weight]

[R can be labelled with N or normal reaction]

[f can be labelled with friction]

(b) $F = m r \omega^2$ [1]

$= (1)(0.3)(0.5 \times 2\pi)^2$ [1]

= 2.96 N [1]

(c) $v = r\omega = (0.3)(0.5 \times 2\pi) = 0.942$ m s^{-1} [1]

By $\frac{1}{2} m v^2 = f s$

$\therefore$ $\frac{1}{2}(1)(0.942)^2 = (10) s$ [1]

$\therefore$ s = 0.0444 m < accept 0.044 m > [1]

OR

By $f = m a$ $\therefore$ $(10) = (1) a$ $\therefore$ a = 10 m s^{-2} [1]

By $v^2 = u^2 + 2 a s$

$\therefore$ $(0) = (0.3\pi)^2 + 2(-10) s$ [1]

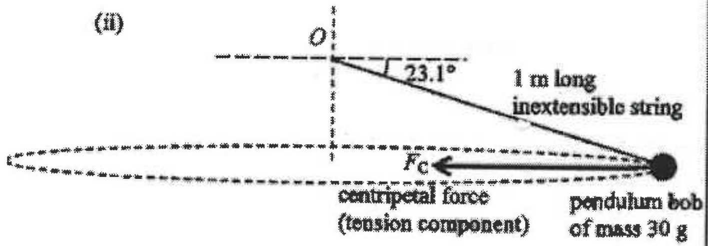
$\therefore$ s = 0.0444 m [1]

10. (a) (i) Rotation rate $= \frac{\omega}{2\pi} = \frac{5.0}{2\pi}$

$= 0.795775$ (rev s^{-1}) ≈ 0.80 (rev s^{-1}) 1M/1A

1

(ii)



F_C correctly indicated. 1A

$F_C = mr\omega^2$

$= (0.03)(1 \times \cos 23.1°)(5.0)^2$ 1M

$= 0.689866$ N ≈ 0.690 N 1A

($F_C = 0.7033402$ N ≈ 0.703 N for $g = 10$ m s^{-2})

OR	
$T\cos\theta = F_C$ and $T\sin\theta = mg$	1M
$F_C = \frac{mg}{\sin\theta}\cos\theta = 0.689866$ N ≈ 0.690 N	1A

3