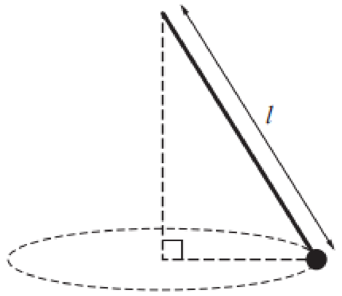
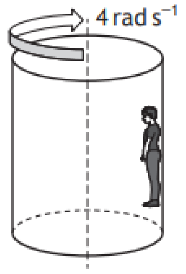
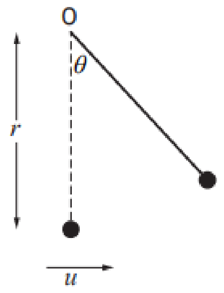
Y	Q	Circular Motion	
24	17	A satellite is in a circular orbit about a planet of radius R metres. The period of the orbit of the satellite is 2000π seconds. The distance of the satellite from the centre of the planet is pR metres, where p is a constant. Show that $$R = \frac{1000^2 a}{p^3}$$ where a is the acceleration in m s^{-2} due to gravity at the surface of the planet.	5
23	13	A planet has a radius of R metres. A satellite, at a height of $5R$ metres above the surface, moves in a circular orbit about the planet. The acceleration due to gravity at the surface of the planet is 3 m s^{-2}. Show that the period of the orbit of the satellite is given by $12\pi\sqrt{2R}$ seconds.	4
23	18	A particle of mass m kg is attached to a light inextensible string. The mass is rotating in a vertical circle of radius r metres. Its velocity at the top of the circle is $2\sqrt{3gr}$ ms^{-1}. (a) Find an expression in terms of g and r for the maximum velocity of the particle.	3
		On another occasion, the same string and mass are set in motion so that the mass has velocity $2\sqrt{gr}$ ms^{-1} at the lowest point of the circle. The angle between the string and the downward vertical is θ. (b) (i) Show that at the point where the tension in the string becomes zero, $\cos\theta = -\frac{2}{3}$.	5
		(ii) Describe the motion of the particle after this point.	1
22	8	A small object of mass m kilograms is placed on a rough horizontal disc, at a distance of 0.07 metres from the centre. When the disc is rotated at a rate of 1.5 revolutions per second, the object is on the point of slipping. Calculate the coefficient of friction between the disc and the object.	5

19	12	A section of motorcycle track consists of a circular bend of radius r metres banked at an angle $\theta°$ to the horizontal. The minimum speed that a motorcyclist can ride around the bend without slipping is $v = \frac{\sqrt{gr}}{10}\,\text{m s}^{-1}$. (a) Show that the coefficient of friction μ can be expressed as $\mu = \frac{100\tan\theta° - 1}{\tan\theta° + 100}$. The circular bend is banked at an angle of 25° to the horizontal and has a radius of 80 m. A motorcyclist approaches the bend at a speed of $28\,\text{m s}^{-1}$. (b) Determine whether the motorcyclist can travel around the bend at this speed without slipping. On another occasion, a different motorcyclist approaches the same bend at the same speed of $28\,\text{m s}^{-1}$, but slides off the track. (c) State one possible reason for this outcome and justify your answer.	 5 4 1
18	5	A body of mass m kg is attached to one end of a light inextensible string of length l metres. The other end of the string is fixed and the body is spun in a horizontal circle so that the path of the string forms a conical pendulum, as shown in the diagram.  The angular speed of the body is ω radians per second. Given that the length of the string is double the radius of the horizontal circle, show that $\omega^2 = \frac{2g}{\sqrt{3}\,l}$.	 5

17	6	A ride at an amusement park consists of a hollow cylinder of radius 3·5 metres which rotates about its vertical axis of symmetry.  When the angular speed reaches 4 rad s^{-1} the floor is lowered and a person remains in contact with the inner surface of the cylinder without slipping. What is the minimum coefficient of friction to prevent the person from slipping?	**4**
17	13	A satellite orbits the Earth at a height of h metres above its surface. (a) If the radius of the Earth is R metres and the acceleration due to gravity experienced at the surface of the Earth is 9 times that experienced at the satellite, find an expression for h in terms of R. (b) If a second satellite is orbiting Earth at a height $3R$ metres above the surface, show that the angular velocity of the second satellite can be expressed as $\frac{1}{8}\sqrt{\frac{g}{R}}$.	**4** **3**
16	9	A velodrome has a circular track of radius 30 metres, banked at an angle of 32° to the horizontal. The coefficient of friction between a bicycle tyre and the track is 0·3. (a) Once the cyclist reaches maximum speed without the bicycle slipping, he cycles for 5 minutes. Assuming he maintains this speed, how many full laps does he complete? (b) Given that air resistance can be ignored and the cyclist is treated as a particle, what other assumption has been made?	**6** **1**

16	17	A light inextensible string of length r metres has one end attached to a fixed point O and the other end is attached to a particle of mass m kilograms. From its equilibrium position, the particle is given a horizontal velocity $u\,\mathrm{m\,s^{-1}}$, as shown in the diagram.  (a) (i) Show that the tension, T, in the string can be expressed as $$T = \frac{mu^2}{r} + mg(3\cos\theta - 2)$$ where θ is the angle between the string and the downward vertical through O. (ii) Determine a condition for u in terms of r and g, so that the particle executes a complete circle. (b) Given that the value of u is $2\sqrt{rg}$, find an expression in terms of r for the height of the particle above its starting position when the string goes slack.	 4 2 3
16 S	13	The distance of the Earth from the Sun is $1{\cdot}50 \times 10^{11}$ metres. The distance of Venus from the Sun is $1{\cdot}08 \times 10^{11}$ metres. Calculate the period of rotation of Venus around the Sun, giving your answer in Earth years. State **one** assumption you have made when calculating your answer.	6
16 S	17	A car of mass M kg is travelling with a speed of $v\,\mathrm{m\,s^{-1}}$ round a circular bend of radius 40 metres on a road banked at 30° to the horizontal. The coefficient of friction between the car tyres and the road surface is μ. (a) Show that the square of the maximum speed the car can travel without slipping is given by $$v^2 = \frac{392(1+\sqrt{3}\mu)}{\sqrt{3}-\mu}$$ The minimum speed that the car can travel round the bend without slipping is $u\,\mathrm{m\,s^{-1}}$. (b) Given that $v = 3u$, calculate the coefficient of friction between the car tyres and the road.	 5 6