1. A car of mass *m* moves in a circular path of radius 75 m round a bend in a road. The maximum speed at which it can move without slipping sideways on the road is 21 m s^{-1}. Given that this section of the road is horizontal,

(a) show that the coefficient of friction between the car and the road is 0.6.

(3)

The car comes to another bend in the road. The car's path now forms an arc of a horizontal circle of radius 44 m. The road is banked at an angle α to the horizontal, where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between the car and the road is again 0.6. The car moves at its maximum speed without slipping sideways.

(b) Find, as a multiple of *mg*, the normal reaction between the car and road as the car moves round this bend.

(4)

(c) Find the speed of the car as it goes round this bend.

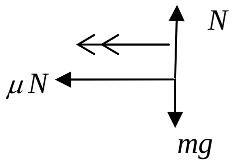
(5)
(Total 12 marks)

2. A circular flywheel of diameter 7 cm is rotating about the axis through its centre and perpendicular to its plane with constant angular speed 1000 revolutions per minute.

Find, in m s^{-1} to 3 significant figures, the speed of a point on the rim of the flywheel.

(Total 3 marks)

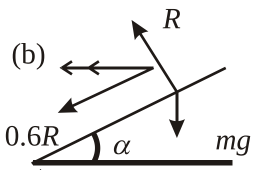
1. (a)



$\frac{mv^2}{r} = \mu N, = \mu mg$ M1, A1

$\mu = \frac{v^2}{rg} = \frac{21^2}{75 \times 9.8} = 0.6*$ A1 3

(b)



R(↑) $R\cos\alpha, \ \mp 0.6R\sin\alpha = mg$ M1, A1, A1

$\Rightarrow \ R\left(\frac{4}{5} - \frac{3}{5}.\frac{3}{5}\right) = mg \Rightarrow R = \frac{25mg}{11}$ A1 4

M1 needs three terms of which one is mg
If cos α and sin α are interchanged in equation this is awarded M1 A0 A1

(c) R(←) $R\sin\alpha, \pm 0.6R\cos\alpha = \frac{mv^2}{r}$ M1, A1, A1

$v \approx 32.5 \text{ m s}^{-1}$ dM1 A1cao 5

M1 needs three terms of which one is $\frac{mv^2}{r}$ or $mr\omega^2$
If cos α and sin α are interchanged in equation this is
also awarded M1 A0 A1
If they resolve along the plane and perpendicular to the plane
in part (b), then attempt at $R - mg\cos\alpha = \frac{mv^2}{r}\sin\alpha$,
and $0.6R + mg\sin\alpha = \frac{mv^2}{r}\cos\alpha$ and attempt to eliminate v M1

Two correct equations A1
Correct work to solve simultaneous equations A1
Answer A1 4

Substitute R into one of the equations M1
Substitutes into a correct equation (earning accuracy marks in part (b)) A1
Uses $R = \frac{25mg}{11}$ (or $\frac{25mg}{29}$) A1
Obtain $v = 32.5$ M1A1 5

[12]

2. 1000 r.p.m = $\dfrac{1000\times 2\pi}{60}$ rad/s B1

$v = 0.035 \times \dfrac{1000\times 2\pi}{60} = 3.67$ ms^{-1} (3 SF) M1 A1

M1 their r × their ω

[3]

1. Part (a) was almost always correct but (b) proved a great discriminator. The best candidates showed how straightforward this could be and solved it as concisely as on the mark scheme but the majority did much less well. Jumping to conclusions was their downfall in (b), with the familiar $R = mg \cos \alpha$ making many appearances. Do candidates pause to reflect how this could be worth 4 marks? Some tried to resolve vertically but forgot to include the friction ($R \cos \alpha = mg$) and arrived at an equally quick answer. Many of these candidates recovered in (c) and wrote a correct horizontal equation but others assumed that the acceleration was along the slope and gained no credit in part (c) either. It is easy to imagine the writers of the following solution passing rapidly on to Q6 delighted at the easy 12 marks they thought they had just earned!

"(b) $R = mg \cos \alpha$, $R = \dfrac{4mg}{5}$, (c) $F = \mu R = \dfrac{mv^2}{r}$, $\therefore$ $v = \ldots$."

As always, significant numbers treated $\dfrac{mv^2}{r}$ as an extra force in an equilibrium equation, so ending up with equations parallel and perpendicular to the plane looking as if the acceleration had been resolved but with wrong signs. There were very few successful solutions which had used these directions. As a topic, circular motion remains poorly understood.

2. This should have been a straightforward starter for most, but full marks were not often seen, usually due to careless numerical errors, rather than lack of a correct method. The most common error was using the given diameter of 7cm as the radius, but mistakes in changing units from cm to m, and in turning revolutions per minute into radians per second were also very common.