8 Read the passage below and answer the questions that follow.

Racing competitions, such as Formula 1, have led to advances in technology that eventually make their way into road vehicles. Formula 1 teams compete to make the fastest vehicle possible within strict rules.

Formula 1 drivers experience large accelerations and decelerations. A Formula 1 car can stop in a straight-line distance of 80 m from a maximum speed of 185 $km\,h^{-1}$.

High accelerations and decelerations are limited by the friction F between the tyres and the road. This is related to the weight W of the car by the equation

$$F = \mu W$$

where μ is the coefficient of friction.

Before use in a race, tyres are kept warm in special tyre blankets. The coefficient of friction varies with the tyre surface temperature, as shown in Fig. 8.1.

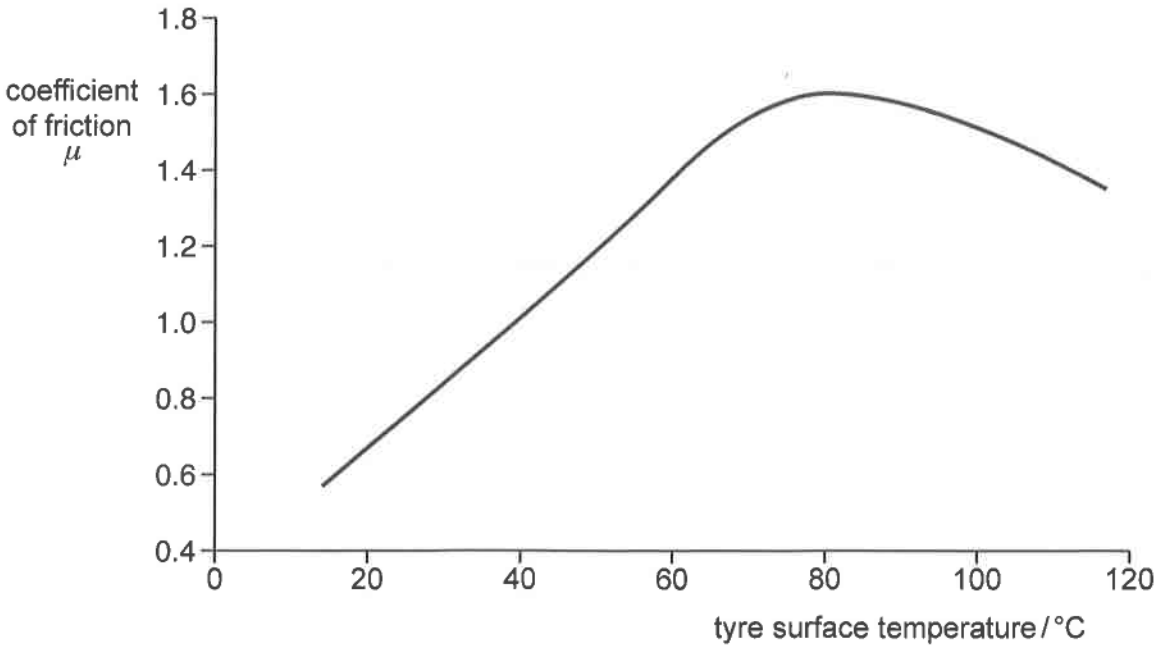

Fig. 8.1

A section through the road surface and a tyre at 20 °C in contact with the road is shown in Fig. 8.2.

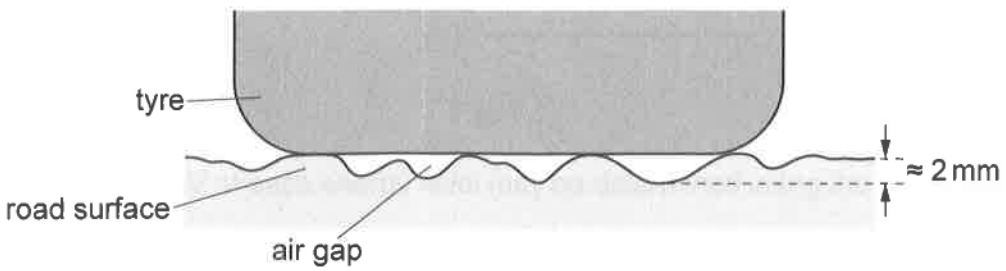

Fig. 8.2 (not to scale)

When the tyre is heated with the tyre blanket, the compound of the tyre becomes softer, increasing the contact area.

In order to make the tightest circular corner in the Singapore Street Circuit, drivers decelerate from 220 km h^{-1} to make it around the corner of radius 30 m. The tyres have to withstand lateral (sideways) accelerations of up to 4*g* during cornering.

The mass of a typical Formula 1 car is about 750 kg. Greater accelerations and cornering speeds may be achieved with greater friction between the tyres and the track. Features of the car, such as rear wings, appear to increase the weight of the car.

When a Formula 1 car accelerates, the weight distribution between the front and rear wheels changes. The cars are rear-wheel drive, which means the accelerating force is provided through the rear wheels. When accelerating, the contact force experienced by the rear wheels increases and this is called 'weight transfer'.

The brakes used on Formula 1 cars consist of carbon fibre discs and pads. There is one set for each of the four wheels. Each set has a mass of 1.2 kg. There are at least 1000 small holes drilled into each disc. These brakes operate more effectively at high temperatures than materials used for the brakes on road vehicles. It is predicted that brakes made from carbon fibre discs and pads will be the next big change to reach the everyday car market.

(a) Calculate the maximum deceleration a Formula 1 driver experiences while braking to rest in a straight line.

deceleration = ... $m\,s^{-2}$ [2]

(b) (i) Determine the maximum speed a Formula 1 car can travel around the tightest circular corner at the Singapore Street Circuit.

maximum speed = ... $m\,s^{-1}$ [3]

(ii) By reference to Fig. 8.1 and Fig. 8.2, suggest and explain why the tyres are heated before use.

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..... [3]

(c) A cross-section of the rear wing on a Formula 1 car is shown in Fig. 8.3.

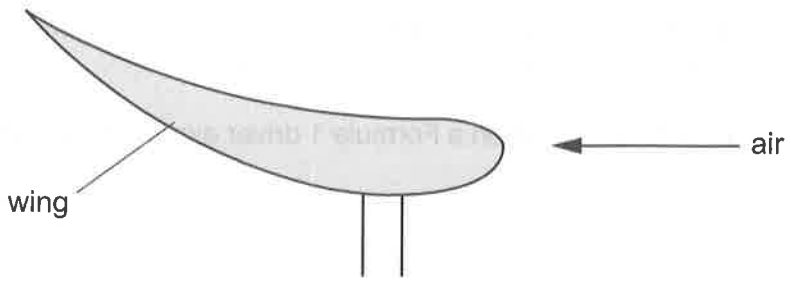

Fig. 8.3

The wing deflects air when the car is moving.

Explain, by reference to the change in momentum of the air, why this air flow appears to increase the weight of the car.

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..... [2]

(d) Some of the forces acting on a Formula 1 car while accelerating from rest are shown in Fig. 8.4.

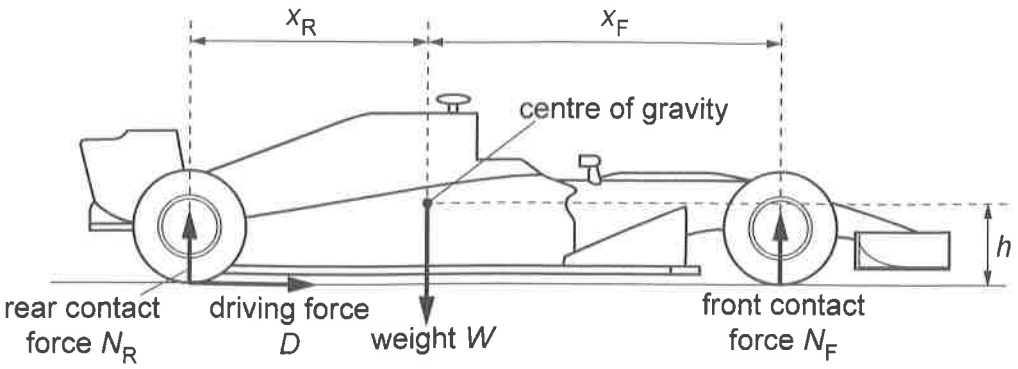

Fig. 8.4

N_R and N_F are the contact forces acting on the rear and front wheels, respectively. W is the weight of the car. D is the driving force acting on the rear wheels.

The centre of gravity is a vertical distance h above the ground. The centre of gravity is a horizontal distance x_R from the rear wheels and a horizontal distance x_F from the front wheels.

For the car accelerating from rest:

(i) take moments about the centre of gravity, to show that

$$N_R = \frac{Wx_F + Dh}{x_F + x_R}$$

[3]

(ii) determine a similar expression to that in **(d)(i)** for N_F.

[1]

(iii) Use your expressions in **(d)(i)** and **(d)(ii)** to show that there is weight transfer between the front and rear wheels.

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..... [2]

(e) **(i)** Calculate the maximum temperature increase $\Delta\theta$ of the carbon fibre brakes when a Formula 1 car brakes to rest from 185 km h^{-1}.

The average specific heat capacity of carbon fibre is 1130 J kg^{-1} K^{-1}.

$\Delta\theta$ = ... °C [3]

(ii) State an assumption you have made in **(e)(i)**.

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..... [1]

(iii) Suggest two reasons why the discs have many small holes.

1. .....

2. .....

[2]

[Total: 22]