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

In the world of competitive cycling, every detail can make a significant difference in a rider's performance. Athletes compete with one another, trying to be a bit better by improving both their bodies and their equipment. Factors such as strategy, equipment efficiency, and physical conditioning all play crucial roles in determining the outcome of races.

Many different types of bicycles exist, with each possessing its own unique strengths. To gain an edge over the competition, bicycle designers are constantly experimenting with different bicycle designs and shapes.

Fig. 8.1 shows the propulsive power *P* required, for 5 different types of bicycles to travel on **flat ground** at different speeds *v.*

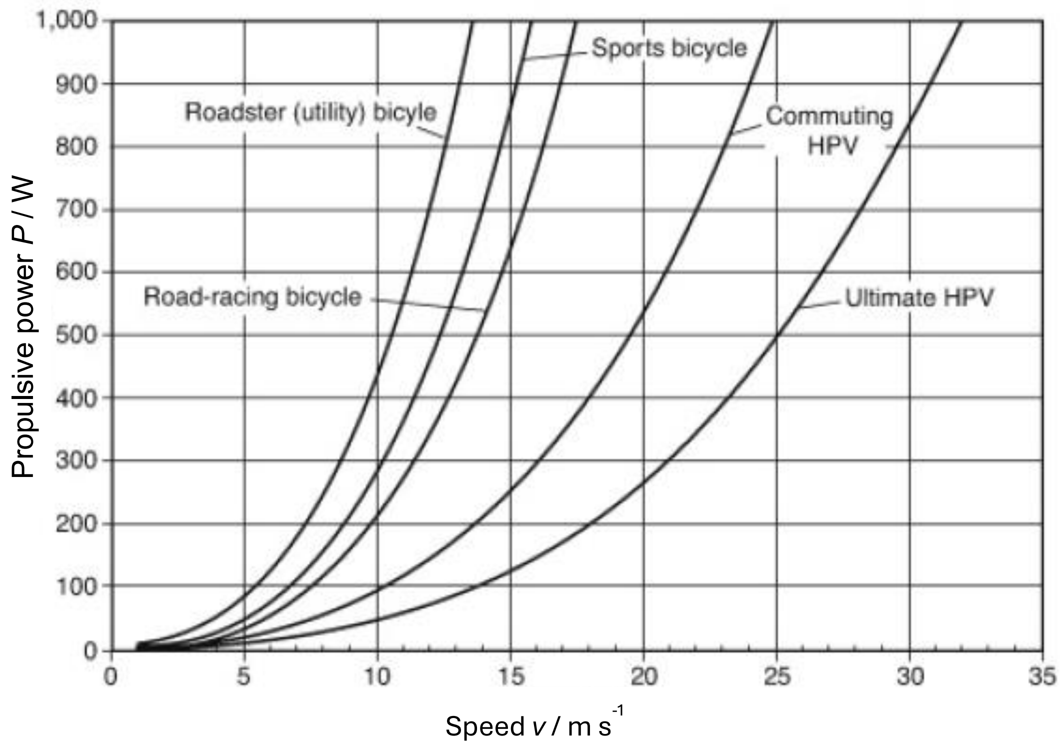

Fig. 8.1

More effort is required to ride fast against the wind or going uphill. A cyclist riding up a slope at a high speed experiences two main forces opposing his motion – slope resistance F_{slope} and air resistance F_{air} .

Slope resistance F_{slope} is related to the steepness of the road. Specifically, F_{slope} refers to the component of the rider (and bicycle)'s weight that acts parallel to the slope. The steepness of a road is commonly referred to as the slope, and is usually expressed as a percentage. Slope is calculated as a fraction ("*rise* over *run*") in which *rise* is the vertical distance and *run* is the horizontal distance. A notable example of a challenging slope is found in the Dirty Dozen bicycle race in Pittsburgh, Pennsylvania. The Canton Avenue hill section of the race is notorious for being one of the steepest in the world, boasting a distance of just 6.4 m, but with a slope of 37%!

Meanwhile, a rider moving at a greater speed experiences greater air resistance F_{air}. For a solo rider, it is suggested that F_{air} is related to the speed v by the equation

$$F_{air} = \frac{1}{2}\rho C_D A v^2$$

where ρ is the air density and the product $C_D A$ is the effective drag area.

For rider safety, the governing body, Union Cycliste Internationale, mandates the use of brakes on bicycles in their events. Brakes can be placed on the front and/or rear wheels of the bicycle, and their effectiveness is limited by the friction F between the wheel and the road.

Theory suggests that F is related to the normal contact force acting at that point N by the equation

$$F = \mu N$$

where μ is the coefficient of friction.

Consequently, both the frictional force acting on the front and rear wheels have different braking efficacy and serve different purposes in assisting the rider to brake effectively.

(a) For a competitive cyclist using an Ultimate HPV bicycle, travelling at constant speed of 25 m s^{-1} on flat ground,

(i) state the propulsive power required.

power = ... W [1]

(ii) Hence, determine the propulsive force provided by the rider.

propulsive force = ... N [2]

(iii) Calculate the effective drag area, $C_D A$ of the cyclist. You may assume that the air density is 1.0 x 10^{-3} g cm^{-3}.

effective drag area, $C_D A$ = ... m^2 [3]

(b) The competitive cyclist in **(a)** takes part in the Dirty Dozen race using the Ultimate HPV bicycle. The combined mass of the cyclist and his bike is 85 kg.

(i) Calculate the slope resistance F_{slope} that the cyclist experiences as he rides up the Canton Avenue hill section.

F_{slope} = ... N [3]

(ii) The cyclist rides up the Canton Ave hill section at a constant speed.

Determine

1. the work done against gravity for this section of the race.

work done = ... J [2]

2. the new propulsive power required by this cyclist if he wishes to maintain a constant speed of 25 m s^{-1} as he climbs the hill.

new propulsive power = ... W [3]

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(c) Fig. 8.3 shows some of the forces acting on the system of cyclist and bicycle as it *brakes*.

The combined weight of the cyclist and his bicycle is W. N_1 and N_2 are the normal contact forces acting on the front and rear wheels, respectively. Consequently, the frictional forces acting on the front and rear wheels are μN_1 and μN_2, respectively.

The centre of mass of the system is located 114 cm above the ground. The rear wheel of the bicycle is located at a horizontal distance of 43 cm from the centre of mass, and the horizontal distance between the centres of both wheels is 107 cm.

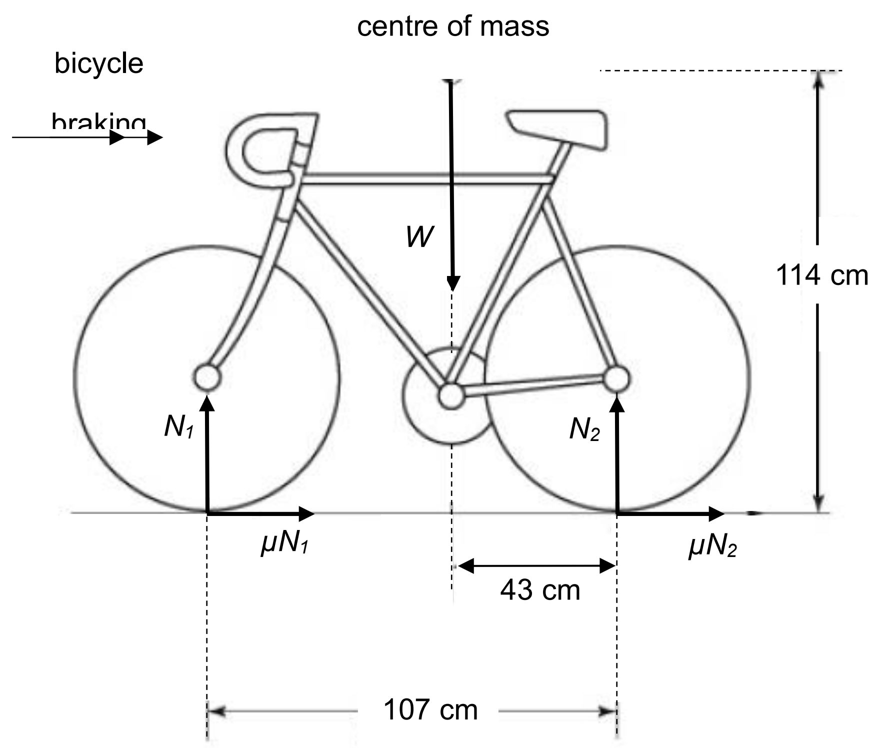

Fig. 8.3

The coefficient of friction μ between the ground and the wheels of the bicycle is 0.37.

(i) Using Newton' second law of motion, determine the magnitude of the cyclist's deceleration.

deceleration = ………………………… $m\ s^{-2}$ [3]

(ii) Taking moments about the centre of mass, show that

$$N_1 = 0.80\ W.$$

[2]

(iii) Determine the ratio of the deceleration contributed by the front wheel to that contributed by the back wheel.

ratio = ... [1]

(iv) When a cyclist brakes too quickly, his centre of mass will tend to move forward due to inertia.

By considering the torques due to individual forces about the centre of mass, explain why a cyclist will tend to flip forward.

....

....

.... [2]

[Total: 22]

END OF PAPER