3 **(a)** Three months ago (20th June 2019), the 'Montezooma's Revenge' at the Knott's Berry Farm theme park in Los Angeles received the 'American Coaster Enthusiasts' Landmark Status as a historic roller-coaster.

Opened in 1978, the ride involves a train being launched by a mechanism that accelerates it to 89 km h^{-1} in 4.5 seconds. As depicted in Fig. 3.1 below, the train will then negotiate a 23.0 m diameter loop before ascending the open-end 45.0 m tall front track. The train then falls backwards under its own weight, going through the loop a second time, ascending the back vertical track and returning to its starting position at the station, brought to a halt through brakes in the station.

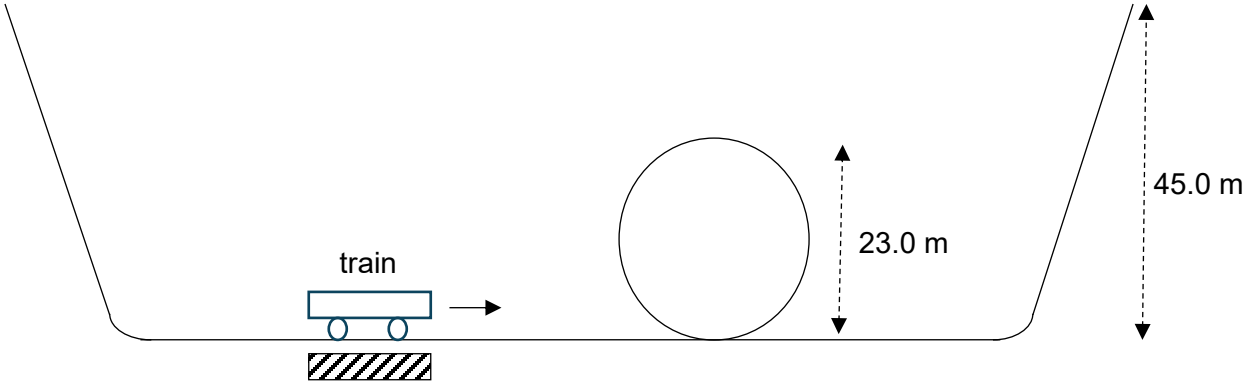

Fig. 3.1

In a typical operation, 28 riders in a single train with 7 cars have a combined mass of 6500 kg. Assume that the track is smooth.

(i) Determine the average power required by the mechanism to bring the train to 89 km h^{-1} in 4.5 s.

power = ……..……. W [2]

(ii) Show that the train will not travel beyond the open-end part of the track after emerging from the loop.

[1]

(iii) Each rider is to be restrained by a lap bar. Should the lap bar's locking mechanism fail and unlock itself as the train negotiates the loop, determine if the rider will fall off the train.

……...

…….. [3]

(b) A straight length of tape winds on to a roll rotating about a fixed axis with constant angular velocity as shown in Fig. 3.2 below. The radius of the roll is increasing at a steady rate.

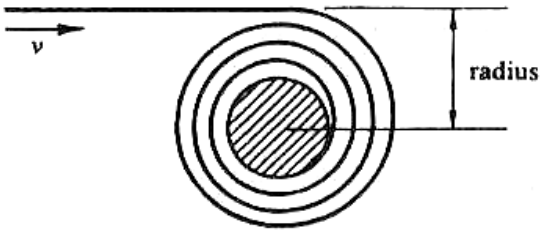

Fig. 3.2

speed ↑

Sketch a speed-time graph to show how the speed v, at which the tape moves towards the roll, varies with time. [2]

(c) A coin of mass m is placed on a horizontal turntable at a distance r from the centre. The maximum frictional force between the coin and the turntable is $\frac{1}{2}mg$. The turntable starts to rotate with increasing angular velocity.

Determine the angular velocity at which the coin will begin to slide. Express it in terms of g and r accordingly. [2]