

# Motion and Force in a Gravitational Field

## Revision Problems 3: Circular Motion

Due: \_\_\_\_\_

Name: \_\_\_\_\_

(20 marks)

1. The mass of a cyclist and bike is 90.0 kg. The cyclist rides around a circular bike track of radius  $1.00 \times 10^2$  m and completes 15.0 revolutions of the track in 10.0 minutes. Calculate her centripetal force. (3 marks)

$$m = 90 \text{ kg}$$

$$r = 100 \text{ m}$$

$$15 \text{ rev} = 600 \text{ s}$$

$$1 \text{ rev} = T$$

$$T = 600 / 15$$

$$T = 40 \text{ s}$$

[1 mark]

$$v = \frac{2\pi r}{T}$$

$$v = \frac{2 \times \pi \times 100}{60}$$

$$v = 15.71$$

[1 mark]

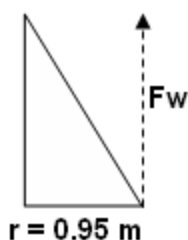
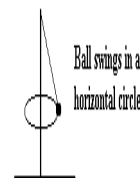
$$F_c = \frac{mv^2}{r}$$

$$F_c = \frac{90 \times 15.71^2}{100}$$

$$F_c = 222 \text{ N}$$

[1 mark]

2. A beach game involves hitting a ball tied to a pole with a piece of string with the ball moving in a horizontal circle. In one game the 0.400 kg ball swings around and around at an angle to the vertical. The ball takes 1.80 s for one revolution. What is the tension in the string if the radius of swing is 0.950 m? (3 marks)



$$F_w = mg = 0.4 \times 9.8$$

$$= 3.92 \text{ N}$$

$$v = \frac{2\pi r}{T} = \frac{2 \times \pi \times 0.95}{1.8}$$

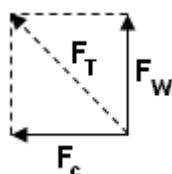
$$v = 3.316 \text{ ms}^{-1}$$

[1 mark]

$$F_c = \frac{mv^2}{r} = \frac{0.4 \times 3.316^2}{0.95}$$

$$F_c = 4.63 \text{ N}$$

[1 mark]



$$F_T = \sqrt{(F_c^2 + F_w^2)}$$

$$F_T = \sqrt{(4.63^2 + 3.92^2)}$$

$$F_T = 6.07 \text{ N}$$

[1 mark]

3. A child jumps on the end of a farm gate and swings it closed. If the gate was at  $90^\circ$  to its closed position, using reasonable estimates for mass, radius and period, determine the child's centripetal acceleration as she closed the gate. (3 marks)

$$m = 30 \text{ kg}$$

$$r = 1.5 \text{ m}$$

$$T = 3 \text{ s}$$

$$v = \frac{1}{4} \times \frac{2\pi r}{T}$$

$$v = \frac{2 \times \pi \times 1.5}{3 \times 4}$$

$$v = 0.785 \text{ ms}^{-1}$$

[1 mark]

$$F_c = \frac{mv^2}{r} = \frac{30 \times 0.785^2}{1.5}$$

$$F_c = 12.3$$

As an estimate,

$$F_c = 12 \text{ N} \quad [1 \text{ mark}]$$

(range between 1N and 300 N)

Maximum 2 s.f. [1 mark]

4. A roller-coaster has a vertical loop of radius 40.0 m. The owners of the roller-coaster advertise that the passengers will feel weightless while riding the loop.

<p>a. What minimum speed would the roller-coaster need to be doing at the top of the loop for this to be true? (2 marks)</p> $F_c = F_w$ $\frac{mv^2}{r} = mg$ <p>[1 mark]</p> <p>Cancel mass</p> $v = \sqrt{rg}$ $v = \sqrt{40 \times 9.8}$ <p><b><u>v = 19.8 ms<sup>-1</sup></u></b> [1 mark]</p>	<p>b. Using your understanding of conservation of energy, what then would be the speed of the roller-coaster at the bottom of the loop? (3 marks)</p> $E_p \text{ lost} = E_k \text{ gained}$ <p>At top, both <math>E_p</math> and <math>E_k</math> as moving so [1 mark]</p> $(\frac{1}{2} mv^2_{\text{top}}) + mgh = \frac{1}{2} mv^2_{\text{bottom}}$ <p>Masses cancel throughout [1 mark]</p> $(0.5 \times 19.8^2) + (9.8 \times 80) = 0.5v^2$ $196.02 + 784 = 0.5v^2$ $980.2 \times 2 = v^2$ $v = \sqrt{1960.04}$ <p><b><u>v = 44.3 ms<sup>-1</sup></u></b> [1 mark]</p>
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5. A 75.0 kg student has an apparent mass of 63.0 kg at the highest point on a steadily rotating Ferris wheel. What is the apparent mass of the student at the lowest point? (4 marks)

Normal weight =  $75 \times 9.8 = 735 \text{ N}$

Apparent weight =  $63 \times 9.8 = 617.4 \text{ N}$

[1 mark]

Difference is due to  $F_c$  which reduces normal weight

$$F_c = 735 - 617.4$$

$$= 117.6 \text{ N}$$

[1 mark]

At bottom:

$$F_T = F_c + F_w$$

$$= 117.6 + 735$$

$$= 852.6 \text{ N}$$

[1 mark]

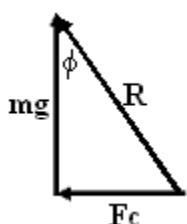
Apparent weight =  $mg$

$$852.6 = m \times 9.8$$

$$m = 87 \text{ kg}$$

therefore student appears to have a mass of 87.0 kg [1 mark]

6. A railway line goes around a curve of radius  $5.00 \times 10^3 \text{ m}$ . It is designed to carry a train travelling at  $1.00 \times 10^2 \text{ ms}^{-1}$ . What would be the angle of banking for the tracks which would result in the best cornering. (2 marks)



$$\tan \phi = \frac{F_c}{mg} = \frac{mv^2/r}{mg}$$

$$\tan \phi = \frac{v^2}{rg}$$

$$= \frac{100^2}{5000 \times 9.8}$$

[1 mark]

$$\tan \phi = 0.2041$$

$$\phi = 11.5^\circ$$

[1 mark]