Motion and Force in a Gravitational Field

Revision Problems 3: Circular Motion

Due: _____

Name: _____ **(20 marks)**

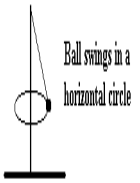
1. The mass of a cyclist and bike is 90.0 kg. The cyclist rides around a circular bike track of radius 1.00 x 10^2 m and completes 15.0 revolutions of the track in 10.0 minutes. Calculate her centripetal force. (3 marks)

m = 90 kg
r = 100 m
15 rev = 600 s
1 rev = T
T = 600 / 15
T = 40 s
[1 mark]

$$v = \frac{2\pi r}{T}$$
$$v = \frac{2x\pi x100}{60}$$
$$v = 15.71$$
[1 mark]

$$F_c = \frac{mv^2}{r}$$
$$F_c = \frac{90x15.71^2}{100}$$
F_c = 222 N
[1 mark]

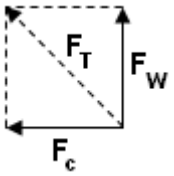
2. A beach game involves hitting a ball tied to a pole with a piece of string with the ball moving in a horizontal circle. In one game the 0.400 kg ball swings around and around at an angle to the vertical. The ball takes 1.80 s for one revolution. What is the tension in the string if the radius of swing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



F_W = mg = 0.4 x 9.8
= 3.92 N

$$v = \frac{2\pi r}{T} = \frac{2x\pi x0.95}{1.8}$$
v = 3.316 ms^{-1}
[1 mark]

$$F_C = \frac{mv^2}{r} = \frac{0.4x3.316^2}{0.95}$$
F_c = 4.63 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 N
[1 mark]

3. A child jumps on the end of a farm gate and swings it closed. If the gate was at 90^0 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 kg
r = 1.5 m
T = 3 s

$$v = \frac{1}{4} x \frac{2\pi r}{T}$$
$$v = \frac{2x\pi x1.5}{3x4}$$
v = 0.785 ms^{-1}

[1 mark]

$$F_c = \frac{mv^2}{r} = \frac{30x0.785^2}{1.5}$$
F_c = 12.3

As an estimate,

F_c = 12 N [1 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.

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)

$F_c = F_w$

$\frac{mv^2}{r} = mg$ **[1 mark]**

Cancel mass

$v = \sqrt{rg}$

$v = \sqrt{40 \times 9.8}$

$v = 19.8\ ms^{-1}$ **[1 mark]**

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)

E_p lost = E_k gained **[1 mark]**

At top, both E_p and E_k as moving so

(½ mv^2 $_{top}$) + mgh = ½ mv^2 $_{bottom}$ **[1 mark]**

Masses cancel throughout

$(0.5 \times 19.8^2) + (9.8 \times 80) = 0.5v^2$

$196.02 + 784 = 0.5v^2$

$980.2 \times 2 = v^2$

$v = \sqrt{1960.04}$

$v = 44.3\ ms^{-1}$ **[1 mark]**

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 x 9.8 = 735 N
Apparent weight = 63 x 9.8 = 617.4 N **[1 mark]**
Difference is due to F_c which reduces normal weight

F_c = 735 – 617.4
= 117.6 N
[1 mark]

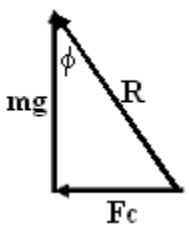
At bottom:

$F_T = F_c + F_w$
= 117.6 + 735
= 852.6 N **[1 mark]**

Apparent weight = mg
852.6 = m x 9.8
m = 87 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 x 10^3 m. It is designed to carry a train travelling at 1.00 x 10^2 ms^{-1}. What would be the angle of banking for the tracks which would result in the best cornering. (2 marks)



$\tan \phi = \frac{Fc}{mg}$ **$\tan \phi = \frac{mv^2/r}{mg}$** **$= \frac{100^2}{5000 \times 9.8}$** **[1 mark]**

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

$\tan \phi = 0.2041$

$\phi = 11.5^0$ **[1 mark]**