Centripetal Acceleration

Objective

To calculate the net force on an object moving in Uniform Circular Motion and compare it to the expected value. To graphically calculate the mass of the object moving in Uniform Circular Motion and compare it to the expected value.

Theory

A. <u>Mass rotating in a circular motion</u>

The mass, M_{bob}, is rotating in a uniform circular motion about the vertical rod in a radius R. Applying Newton's 2nd law in the radial direction gives a net force in the radial direction given by $F_{net} = M_{bob}a_r$, where $a_r = \frac{v^2}{R}$. The speed of the mass M_{bob} is given by $v = \frac{2\pi R}{T}$ and thus $a_r = \frac{4\pi^2 R}{T^2}$. Therefore, $F_{net} = M_{bob}\frac{4\pi^2 R}{T^2}$.

B. <u>Mass in Equilibrium</u>

When the mass M_{bob} is in equilibrium and the radius R is the same as it was when it was rotating in a uniform circular motion. If this is the case, then the tension force, which equals the weight of the hanging mass $W_{hanging}$, must be equal to the net force in the radial direction $F_{net} = M_{bob}\frac{4\pi^2 R}{T^2}$ when the mass M_{bob} is rotating in uniform circular motion. We will be comparing these two values taking $W_{hanging}$ to be the expected value.

Apparatus

- Centripetal force apparatus
- Set of masses and hanger
- Stopwatch

- String
- Level
- Ruler

Procedure

Part 1(Uniform Circular Motion – Diagram 1)

1. Remove mass Mbob from the apparatus and measure the mass with triple-beam balance. Place mass Mbob back on the apparatus - but do not attach the spring
2. With the spring not attached, level the platform with the level and align the mass pointer with the vertical pointer.
3. Measure the radius R.
4. Attach spring to mass Mbob.
5. Rotate Mbob at a constant speed so that the bob pointer is aligned with the vertical pointer.
6. Measure the time for 20 revs 3 times and calculate the average period.
7. Calculate the radial acceleration using the average period.
8. Calculate the net force Fnet.

Part 2 (Static Equilibrium – Diagram 2)

1. Leave the spring attached to the mass Mbob.
2. Attach string with hanger to mass Mbob.
3. Add mass to the hanger until the mass pointer and vertical pointer are aligned just as it was when Mbob was rotating in a uniform circular motion.
4. Calculate the weight Whanging of the hanging mass.

5. Compare Whanging with Fnet. Take Whanging to be the accepted value and use g =9.80 m/s^2

6. Repeat Part (1) and Part (2) above for a total of 3 different radii.

Calculations

Figure 1

R (cm)	Mbob(kg)	t1 (20 revs)	T1 (s)	t2 (20 revs)	T2(s)	t3(20 revs)	T3(s)	Tave
15	.3508	5	.5	6	.6	9	.9	.667
18	.3508	5	.5	7	.7	12	1.2	.8
21	.3508	6	.6	7	.7	12	1.2	.833

Figure 2

R(cm)	ar	F1(N)	Mhang(kg)	Whang(N)	%error
15	4.669309368	13.31046	0.5517	5.412177	13.72585619
18	3.89109114	11.09205	0.7517	7.374177	47.23355379
21	4.183701194	11.92617216	1.3517	13.260177	68.4491301

Data Analysis

After three runs with 3 different radii, we concluded that an unaccounted force was creating a tangential acceleration that was higher than originally calculated. Specifically, the force required to lower the second hanging mass was substantially higher than the theoretical value, meaning that a force working against the gravitational force acting on the second hanging mass was at play. This force was later concluded to be the force of the spring acting on the bob facing inwards to the axis of rotation.

Conclusion

To conclude, we had percent errors 13.73, 47.23, and 68.45. The high percent error can be attributed to the fact that the force exerted by the spring on the bob was non-negligible.

Specifically, the spring constant was high enough to extend out to the desired radius the system had to overcome the spring force by accelerating past the minimum acceleration needed to extend the bob out to the desired radius. This means that the correct acceleration would have been the difference in the force experienced by the bob due to tangential acceleration and the inward force exerted by the spring. This error can be overcome in future experimentation by utilizing a spring with a spring constant low enough to exert a negligible force on the bob. If a high spring constant needs to be used, calculations should include a free-body diagram resolving the horizontal forces into one vector.