OCR A Physics A-level

Topic 5.3: Circular motion

Notes

Kinematics of circular motion

The radian

Radians can be used instead of degrees to measure angles. A radian is the angle subtended by a circular arc with a length equal to the radius of the circle. There are 2π radians in a full circle. To convert an angle from degrees to radians, divide it by 360 and then multiply by 2π.

Period and frequency

The **period**, T, is the time, in seconds, taken for an object to travel a full circle. The **frequency**, *f*, measured in Hertz (Hz) is the number of full circles completed in one second. The two are related by the formula $f = 1/T$.

Angular velocity

The **angular velocity**, ω, of an object moving in a circle is the **rate of change of angle**. It is given by the formula $\omega = \frac{\theta}{t}$, where θ is the angle the object has travelled through in the time *t*. It is measured in $rads^{-1}$, so the angle must be measured in radians and the time in seconds. In a time of one period, T, the object will complete a full circle, with an angle equal to 2π radians. The formula for angular velocity can therefore be written as

$$\omega = \frac{2\pi}{T} = 2\pi f$$

Centripetal force

Centripetal force

When an object travels in a circle, its direction is **constantly changing**. As velocity is given with respect to direction, this means the velocity of the object is also constantly changing, even though the speed maybe constant. In order for the velocity to change, the object must be accelerating, and this acceleration is provided by the **centripetal force**. Centripetal force is the **net** force which acts **perpendicular** to the direction of the velocity, towards the centre of the circle.

The speed *v* of a object moving in a circle of radius r is given by the formula

$$v = \frac{2\pi r}{t} = \omega r$$

The acceleration of the object is equal to the rate of change of velocity. The centripetal acceleration for an object moving in a circle is given by the formula

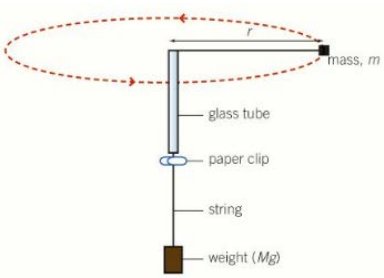
$$a = \frac{v^2}{r} = \omega^2 r$$

Using the formula F=*ma*, the centripetal force can be determined by substituting in the expression for centripetal acceleration, to give

$$F = \frac{mv^2}{r} = m\omega^2 r$$

The centripetal force can come from many places, e.g. gravitational fields, friction, tension in a rope. It is important to remember that centripetal force is the net force acting towards the centre of the circle, so when an object experiences multiple forces (such as normal contact force acting in and gravitational force acting out) the **resultant force** must be used.

Techniques to investigate circular motion



Circular motion can be investigated experimentally by tying a bung, with mass *m*, to a piece of string, and threading it through a glass tube. The other end of the string has a weight, with mass *M*, suspended from it. This provides the centripetal force, F = *Mg*, as the tension throughout the string is constant. The string is whirled in a circle, and the time taken for a complete rotation is recorded. The mass of the weight is altered and the experiment repeated.

As the centripetal force is given by the formula $\frac{mv^2}{r}$, and provided by the weight on the end of the string, *Mg*, we can equate the two to get

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

By measuring the radius of the circle and using the time for one complete oscillation, the velocity can be determined. When v^2 is plotted against *M*, a straight line graph which passes through the origin should be produced.