Conical Pendulum 18.2

A Level

A small sphere of mass $2.0\,\mathrm{kg}$, attached to the end of a light string of length $90\,\mathrm{cm}$ at 24° to the vertical, moves in a horizontal circle.

Part A Tension

Calculate the tension T in the string.

Part B Height above position at rest

Calculate the height h by which the mass is raised above its position at rest.

Conical Pendulum 18.3

A Level

A lead ball of mass $45\,\mathrm{g}$ is attached to the end of an $80\,\mathrm{cm}$ long light string and swung around in a horizontal circle at high speed.

If the string snaps at a tension of $195\,\mathrm{N}$, what is the maximum frequency of rotation f possible?

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Conical Pendulum 18.7

A Level

C C C

An aircraft travelling at $160\,\text{knots}$ maintains its altitude during a circular banked "rate one turn", which is a $3.0^\circ\,\text{s}^{-1}$ turning rate. ($1\,\text{knot} = 0.514\,\text{m}\,\text{s}^{-1}$)

At what angle to the horizontal are the wings of the plane?

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Vertical Circles 19.1

A Level

Quantities:

u speed at bottom $(\mathrm{m\,s^{-1}})$
v speed at top $(\mathrm{m\,s^{-1}})$
W weight (N)
r radius of circle (m)
m mass (kg)
N normal reaction (N) [$+$ means $\uparrow$]
a centripetal acceleration $(\mathrm{m\,s^{-2}})$
F resultant force (N)

Equations:

$$F = ma \qquad W = mg \qquad a_{\text{top}} = \frac{v^2}{r} \qquad a_{\text{bottom}} = \frac{u^2}{r}$$

Gain in E_{GP} = Loss in E_{K}, so

$$mg \times 2r = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$$

An object travels in a vertical circle. Using the equations above, and writing upwards normal reactions as positive, write an equation for:

Part A N (bottom) using W, m, a

N for the mass at the bottom using W, m and a.

The following symbols may be useful: `N, W, a, m`

Part B N (bottom) using m, r, g, u

N for the mass at the bottom using m, r, g and u.

The following symbols may be useful: `N, g, m, r, u`

Part C N (top) using W, m, a

N for the mass at the top using W, m and a.

The following symbols may be useful: `N, W, a, m`

Part D N (top) using m, r, g, v

N for the mass at the top using m, r, g and v.

The following symbols may be useful: `N, g, m, r, v`

Part E N (top) using m, r, g, u

N for the mass at the top using m, r, g and u.

The following symbols may be useful: `N, g, m, r, u`

Part F v if $N = 0$

the speed v needed at the top if $N = 0$.

The following symbols may be useful: `N, g, m, r, v`

Part G u if $N = 0$ at top

the speed u needed at the bottom if $N = 0$ at the top.

The following symbols may be useful: `N, g, m, r, u`

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Vertical Circles 19.2

A Level

Calculate the normal reaction when a $1200\,\mathrm{kg}$ car is half way over a hump back bridge if it is travelling at $8.0\,\mathrm{m\,s^{-1}}$. The radius of the bridge's arc is $23\,\mathrm{m}$.

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Vertical Circles 19.3

A Level

A $1200\,\text{kg}$ car is half way over a hump back bridge. The radius of the bridge's arc is $23\,\text{m}$.

Calculate the speed at which the wheels would just leave the ground at the top of the bridge.

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Vertical Circles 19.6

A Level

A person feels weightless when the normal reaction $N = 0$.

Calculate the speed a roller-coaster car would have to be travelling at the top of a radius $r = 4.5\,\text{m}$ loop in order for the riders to experience weightlessness at the top.

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Vertical Circles 19.8

A Level

When roller-coaster riders describe their rides, they call the ratio N/mg the *g-force* (i.e. $\text{normal reaction} \,/\, \text{weight}$. This is not a scientific term). In this formula, N is taken as positive if it is directed upwards through the rider's body towards their head. A roller-coaster is designed to give $N/mg = 2.5$ at both the top and the bottom of the ride. The loop is not circular. The rider sits in a train which runs around the inside of the loop. The top of the loop is curved with a $7.6\,\text{m}$ radius.

Part A Rider at rest

State the value of N/mg for a rider sitting at rest in the train.

Part B Speed at top

Calculate the speed of the train at the top of the loop.

Part C Speed at bottom

If there is no friction, and the top of the loop is $21\,\text{m}$ above the bottom, how fast will the train travel at the bottom of the loop?

Part D Radius at bottom

Calculate the radius of the loop at the bottom of the track.

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Elastic Circular Motion

A Level

C C C

A mass, m of $0.050\,\mathrm{kg}$ is attached to one end of a piece of elastic of unstretched length, $l = 0.50\,\mathrm{m}$. The force constant, k of the elastic (i.e. the force required to produce unit extension) is $40\,\mathrm{N\,m^{-1}}$. The mass is rotated steadily on a smooth table around a fixed point in a horizontal circle of radius $r = 0.70\,\mathrm{m}$.

What is the approximate speed of the mass?

- $5.7\,\mathrm{m\,s^{-1}}$
- $11\,\mathrm{m\,s^{-1}}$
- $20\,\mathrm{m\,s^{-1}}$
- $15\,\mathrm{m\,s^{-1}}$
- $2.4\,\mathrm{m\,s^{-1}}$

Adapted with permission from UCLES, A Level Physics, June 1987, Paper 1, Question 9.

Gameboard:

STEM SMART Physics 24 - Applied circular motion

Sphere Under Gravity

A Level

A small sphere is attached to a fixed point by a string of length $l = 30\,\text{cm}$, and whirls round in a vertical circle under the action of gravity at such speed that the tension in the string when the sphere is at its lowest point is three times the tension when the sphere is at its highest point.

Find the speed of the sphere at its highest point.

Adapted with permission from UCLES, Higher School Certificate Physics, June 1930, Paper 2, Question 4.