**teacher guide**

**The Standard Model 3:**

**Particle calculations**

# Components

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|  | NAME | DESCRIPTION | AUDIENCE |
|  | *Particle calculations*teacher guide | This guide suggests questions that may be used by students to develop their understanding of particle physics. | teachers |
|  | *Working with particles*worksheet | This student worksheet contains questions about particles and their properties. | students |

Purpose

Students reinforce their explanations of particle physics through calculations in the context of the Large Hadron Collider.

# Outcomes

Students:

* use experimental data to calculate particle properties;
* calculate particle motion in a magnetic field;
* interpret tracks in a bubble chamber.

# Activity summary

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| --- | --- |
| ACTIVITY | POSSIBLE STRATEGY |
| Students complete worksheet, *Working with particles*. | individual |
| Class discussion of points arising from worksheet. | whole class |

Teacher notes

**Question 1** in the worksheet uses the context of mesons created by proton-proton collision in the Large Hadron Collider to explore time dilation. Mesons are short-lived particles, with a mean lifetime of

1.5 x 10-12 s. However their tracks in the LHC are around 1 cm long. Even at the speed of light we might expect mesons to decay before they have travelled 0.05 cm.

The anomaly is explained because time is dilated for a fast-moving meson, from the point of view of the stationary observer who measures the 1 cm track.

The Lorentz equation for time dilation can be used to determine what factor of v/c gives rise to the observed dilation. See worksheet answers for details of the calculation.

**Question 2** also uses the LHC as a context, comparing the total beam energy to the kinetic energy of a Transperth train. Students have to convert between energy units of electron-volts and joules.

**Questions 3** and **4** explore motion of charged particles in a magnetic field. The first of these questions introduces derivation of the formula to calculate radius of curvature by equating the force on a charged particle moving perpendicular to a magnetic field:

F = q v B

and the centripetal force of an object undergoing circular motion:

F = m v2 / r Rearranging, this gives:

r = m v / q B

**Question 4** is a qualitative analysis of particle tracks in a bubble chamber. Direction of curvature of tracks is used to infer charge on particles and demonstrate charge conservation.

# Technical requirements

The teacher guide and worksheet require Adobe Reader (version 5 or later), which is a free download from [www.adobe.com.](http://www.adobe.com/) The worksheet is also available in Microsoft Word format.

# Acknowledgements

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# Associated SPICE resources

*The Standard Model 3: Particle calculations* may be used in conjunction with related SPICE resources to teach the topic of the Standard Model.

|  |  |
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| DESCRIPTION | LEARNING PURPOSE |
| The Standard Model (overview)This learning pathway shows how a number of SPICE resources can be used in teaching students about the Standard Model. |  |
| *The Standard Model 1: Big physics*Students watch a TED talk on the Large Hadron Collider. What do scientists hope to discover with this machine? | **Engage** |
| *The Standard Model 2: Structure of matter*A series of presentations guide discussion of the fundamental building blocks of the Universe. | **Explore** |
| *The Standard Model 3: Particle calculations*Students perform calculations using properties of fundamental particles. | **Explain** |
| *The Standard Model 4: Quantum approach*A presentation introduces a quantum view of particle interactions. | **Elaborate** |