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| **Materials for prosthetics** | | | |
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| Analyse data to find the best material for a prosthetic foot | | | |
| **Subject(s):** Science, Design & Technology, Mathematics  **Approx time:** 30-45 mins |  | | **Key words / Topics:**   * prosthetics * smart materials * stress * strain * elasticity * applications & implications of science * standard form * dimensions * gradient * measurements |
| **Suggested Learning Outcomes** |  | |  |
| * Be able to make the link between material properties and material usage * Understand how smart materials are used in a real life context * Use and manipulate material-related data | | | |
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| **Introduction** |  | |  |
| The development of new materials with incredible properties is changing the way we live. From LCD TVs to super light airliners, these materials have quickly found their way into pretty much all of the modern technology around us.  One area where modern materials have made a huge impact is in the development of prosthetic devices. Some of these devices are beginning to outperform ‘natural’ body parts.  The resources within this, and the related activities, encourage students to investigate the properties of smart materials and carry out some data manipulation. Students will also explore the possible moral and ethical issues associated with people potentially choosing to replace healthy body parts with artificial prostheses because they offer higher performance.  **Purpose of this activity**  This activity is designed as a main lesson activity. Students carry out some data manipulation to find the best material from which to make a prosthetic foot. The activity offers strong opportunities for cross-curricular work with Mathematics. | | | |
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| **Activity** |  | | **Teacher notes** |
| **1.** Split the class into teams.Students work as teams of engineering materials consultants and have to find the best material from which to make a prosthetic foot. Explain the scenario given on the **Which Material (Brief)**. *(ca three minutes)*  **2.** Using the **Which Material (Brief)** and the **Materials Data Sheet (Handout)**, students will plot graphs of stress against strain for seven different materials and calculate the gradient in order to find the stiffness for each material.  Based on this information, students should select which of the seven materials is the most suitable for the construction of the foot.  **3.** Students present their recommendations to the rest of the class. Other teams comment on their recommendations.  Alternatively, teams can hand their work in. *(ca 12 minutes)*  *Continue the lesson with the practical activity ‘Which Material 2’ (see* ***Related activities*** *section below)*   * Students could research which real materials have properties similar to the one they have chosen for the prosthetic foot. * Students could be asked to consider whether there will come a time when people will want perfectly healthy natural body parts removed and replaced with prosthetics because they offer better performance. If they think this is likely to be so they could be asked to consider what the possible ethical and moral implications might be. * Students could test their knowledge of materials and prosthetics by watching the films and then completing the **Nature Reinvented quiz** on the IET Faraday website. |  | | icon-doc **Which Material (Brief)**  **icon-doc Materials Data Sheet (Handout)**  An additional **Definitions (Handout)** is also provided. This sheet provides students with definitions of some of the terms used in the activity which they may not be familiar with.  Answers to the exercise can be found on the sheet **Materials Data Sheet (Answers)**. *(ca 30 minutes)*  film **Nature Reinvented** film  **film Bionic Limbs** film |
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| **Differentiation** |  | |  |
| **Basic** |  | | **Extension** |
| Give students squared paper rather than graph paper with scaled axis. Students can then more easily plot the graphs. Students could even use a graphic package like MS Excel to aid them in calculating the gradient. It may also be useful to briefly go over the method for finding the gradient of a straight line graph. |  | | Define stress and strain for students and ask them to suggest suitable tests for determining stress and strain before giving them the **Materials Data Sheet****(Handout)**.  Students can assume that the material to be tested is in the form of a piece of circular section metal wire. Their suggestions need only be general i.e. measure the diameter of the wire, calculate its cross-sectional area and then hang a known mass from it. Multiply the mass in kilograms by 9.8 m/s2 to find the force (weight) in Newtons. Then calculate the stress by dividing the force by the cross-sectional area.  For strain, simply measure the length of the wire before the force is applied, measure the wire while the force is being applied and calculate the extension. Strain is then calculated by extension/original length.  It could also be explained to more able students that the value for ‘stiffness’ which they are finding is actually called the Young modulus or the modulus of elasticity. |
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| **Resources** |  | | **Required files** icon-docicon-pdficon-ppt |
| * Graph Paper |  | | icon-doc Which Material (Brief)  icon-doc Materials Data Sheet (Handout)  icon-doc Materials Data Sheet (Answers)  icon-doc Definitions (Handout) |
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| **Additional websites** |  | |  |
| * NOVA Online: Some useful teacher reference material can be found on the NOVA website (of the Public Broadcasting Service (PBS)) at [www.pbs.org/wgbh/nova/eheart/manmade.html](http://www.pbs.org/wgbh/nova/eheart/manmade.html) which shows an annotated diagram of a human body with various prostheses in place. * Professor Kevin Warwick: ([www.kevinwarwick.com](http://www.kevinwarwick.com)) Based at the University of Reading and has implanted several computer chip devices in his left arm which allow him to interface directly with a range of equipment * Daily Mail Online: An article about Paralympic T44 100metres champion Johnny Peacock, an amputee who uses a prosthetic leg to help him compete (<http://www.dailymail.co.uk/sport/othersports/article-2327184/Jonnie-Peacock-changes-blades-hopes-avoid-row--Laura-Williamson.html>). | | | |
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| **Related activities (to build a full lesson)** |  | |  |
| **Starters** (Options)   * FILM: Bionic Limbs * FILM: Nature Reinvented * FILM: Prosthetic Design * ACTIVITY: Engineering prosthetics * ACTIVITY: Prosthetic devices   **Main** (Options)   * ACTIVITY: Prosthetic replacements * ACTIVITY: Smart Materials 1 * ACTIVITY: Smart Materials 2 | | **Extension** (Options)   * ACTIVITY: **Materials for prosthetics** * ACTIVITY: Materials for prosthetics 2   **Plenary**   * GAME: Bionic Games * QUIZ: Nature Reinvented * Opportunities within activity for presentations, peer/self assessment * Reflection on Objectives and PLTS skills used | |
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| **The Engineering Context** film |
| * **The story** Nature Reinvented * **The story** Bionic Limbs |

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| **Curriculum links** | |
| **England: National Curriculum**  Science   * KS3 3a, 3b, 3c, 3d, 4a, 4b, 4c, 21c * KS4 1.1a,b, 1.2a,b, 1.3a,b,c, 2.2d   Design & Technology   * KS3 3b, 3d, 4a   Mathematics   * KS3 1a, 1b, 1e, 1f, 1g, 2a, 2c, 2g, 3b, 3c, 4a, 4d, 4l, 4o, 5b, 5m, 6a, 6j, 9a, 9b * KS4 1.1a, 1.1b, 1.1c, 1.2a, 1.2b, 1.3b, 2.1a, 2.1d, 2.2a, 2.2h, 2.2k, 2.2l, 2.2n, 2.2o, 2.4a, 2.4b, 3.1a, 3.1b, 3.2a, 3.2g, 4d   GCSE  AQA Design and Technology   * 3.1.1, 3.1.3, 3.1.6.2, 3.2.2, 3.2.5, 3.3.7   Edexcel Design and Technology   * 1.1.4, 1.2.1, 1.2.2, 1.4.1, 1.4.2   Eduqas Design and Technology  Technical principles - Core knowledge and understanding   * 1. The impact of new and emerging technologies on: industry, enterprise, sustainability, people, culture, society, the environment, production techniques, systems * 2. How the critical evaluation of new and emerging technologies informs design decisions; considering contemporary and potential future scenarios from different perspectives, such as ethics and the environment * 4. Developments in modern and smart materials, composite materials and technical textiles   Technical principles - In-depth knowledge and understanding   * 2. The way in which the selection of materials or components is influenced by a range of factors, such as functional, aesthetic, environmental, availability, cost, social, cultural and ethical factors * 3. The impact of forces and stresses on materials and objects and the ways in which materials can be reinforced and stiffened   Designing and making principles - Develop and apply core knowledge, understanding and skills   * 2. Identify and understand client and user needs through the collection of primary and secondary data.   OCR Design and Technology   * 1.1a, 1.2a, 2.1a, 2.2a, 3.1a, 5.1f, 5.2a, 5.2b, 5.2c   AQA Engineering   * 3.5   AQA Mathematics  N13, A14, S2  Edexcel 9-1 Mathematics  N13, A14, S2  Eduqas Mathematics  FN13, HN13; FA13, HA14; FS3, HS3  OCR Mathematics  7.04a, 10.01a, 12.02a | **Northern Ireland Curriculum**  Science  Developing pupils’ Knowledge, Understanding and Skills   * develop skills in scientific methods of enquiry to further scientific knowledge and understanding: * planning for investigations, obtaining evidence, presenting and interpreting results; * chemical and material behaviour: structures, properties, uses of materials * forces and energy: forces and energy transfer   Technology & Design  Developing pupils’ Knowledge, Understanding and Skills   * manufacturing – selecting and using materials fit for purpose; safe use of a range of tools and processes appropriate to materials, demonstrating accuracy and quality of outcome   (Objective 1) Developing pupils as Individuals   * abide by health and safety rules when using tools, machines and equipment   (Objective 3) Developing pupils as Contributors to the Economy and the Environment   * identify product needs and pursue sustainable harmonious design solutions in a local outdoor/indoor context   Learning Outcomes   * demonstrate practical skills in the safe use of a range of tools, machines and equipment; * work effectively with others; * demonstrate self management by working systematically, persisting with tasks, evaluating and improving own performance; * communicate effectively in oral, visual (including graphic), written, mathematical and ICT formats showing clear awareness of audience and purpose.   Mathematics and Numeracy  Developing pupils’ Knowledge, Understanding and Skills   * the application of mathematical skills to real life and work situations   (Objective 3) Developing pupils as Contributors to the Economy and the Environment   * explore how the skills developed through mathematics will be useful to a range of careers   Learning Outcomes:   * decide on the appropriate method and equipment to solve problems – mental, written, calculator, mathematical instruments or a combination of these; * communicate effectively in oral, visual, mathematical and ICT formats, showing clear awareness of audience and purpose. |
| **Scotland: Curriculum for Excellence**  Sciences   * SCN 4-16a, SCN 4-20a   Technologies   * TCH 3-01a, TCH 2-12a / 3-12a, TCH 3-13a, TCH 3-13b, TCH 3-14a   Numeracy and Mathematics   * MNU 2-03a, MNU 3-03b, MNU 3-07a, MNU 2-09c, MNU 3-09a | **Wales: National Curriculum**  Science  KS3 Skills (Communication 2, 3)  KS4 Skills (Communication 1, 2, 3; Enquiry and Practical Skills 2)  KS4 Range (Chemical and material behaviour 4)  Design & Technology   * KS3 Skills (Making 1, 2, 5) * KS3 Range (Resistant materials and textiles 14; Systems and controls 16, 17, 18)   Mathematics  KS3 Skills  Solve mathematical problems   * select, organise and use the mathematics, resources, measuring instruments, units of measure, sequences of operation and methods of computation needed to solve problems * use their knowledge of mathematical relationships and structure to derive facts that they have not yet learned, and to solve numerical problems * develop their skills of estimating and measuring; recognise limitations on the accuracy of data and measurement; select an appropriate degree of accuracy   Communicate mathematically   * read mathematical forms of communication, including tables, diagrams, graphs, mathematical texts and ICT * present work clearly, using diagrams, labelled graphs and symbols   Reason mathematically   * evaluate results by relating them to the initial question or problem   KS3 Range  Measures and money   * find perimeters, areas and volumes of common shapes   KS4 Skills  Solve mathematical problems   * use their knowledge of mathematical relationships and structure to derive facts that they have not yet learned, and to solve numerical problems * develop their skills of estimating and measuring; recognise limitations on the accuracy of data and measurement; select an appropriate degree of accuracy   Communicate mathematically   * present work clearly, using diagrams, labelled graphs and symbols   Reason mathematically   * evaluate results by relating them to the initial question or problem   KS4 Range  Number   * use index notation and standard form   Measures and money   * use compound measures * use and interpret scale on graphs, maps and drawings * distinguish between formulae by considering dimensions   Handling data   * interpret information given in a wide range of graphs, diagrams and statistics, particularly real-life data |
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| **Assessment opportunities** | | |
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| **Personal, learning & thinking skills (PLTS)** | | |
| * Creative Thinker * Team Worker | | |