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| **Materials for a robotic arm** | | | |
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| Investigate the properties of smart springs and see how they might be used as muscles in a robotic arm | | | |
| **Subject(s):** Science, Design & Technology, Maths  **Approx time:** 60 mins |  | | **Key words / Topics:**   * prosthetics * smart materials * stress * strain * elasticity * applications & implications of science and technology * measurements * vectors |
| **Suggested Learning Outcomes** |  | |  |
| * Be able to explain why a material is chosen for a use based on its properties * Describe 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 most 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 practical activity is designed as a main lesson activity and as an extension to the related activity ‘Which Material? 1’ in which students carry out some data manipulation to find the best material from which to make a prosthetic foot. In this practical activity students investigate the properties of smart springs and see how they might be used as muscles in a robotic arm. | | | |
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| **Activity** |  | | **Teacher notes** |
| **1.** Arrange students into teams of three or four and explain the session.  If necessary also explain the properties of smart springs and shape memory alloys.  Demonstrate a smart spring so that the class knows what to expect their spring to do. *(10 minutes)*  **2.** Hand out copies of the **ExperimentSheet (Handout)**. Run through the experiment with the class.  Their task will be first of all to suspend the spring from a retort stand and examine how it works. A circuit diagram is given on the **ExperimentSheet (Handout)**. Students should examine the spring and conclude that contraction of the spring is caused by the heating effect of the current passing through the spring.  The springs should be capable of lifting between 0.5 and 1 kilogram. It is important that the maximum mass they can lift is known prior to the lesson so that students can be told not to exceed it. Trying to lift masses which are too heavy can damage the springs.  Students can then be given the hinged wooden arms to act as robotic arm joints (as on the **Helpsheet (Handout)**). *(40 minutes)*  **3.** If time allows, students can present their findings back to the class, or they could simply be written up as a report discussing the suitability of such materials for use in robotic arms. *(10 minutes)* |  | | **Pre-lesson preparation: it will be necessary to pre-test springs so that appropriate slot masses can be made available and to check that the batteries suggested below will provide a supply voltage of 3V and a current of up to 3A.**  **Safety note: the springs need to reach a temperature of approximately 70⁰ Celsius in order to contract.**  icon-doc Experiment Sheet (Handout)  Students must be warned not to touch the springs while they are in operation as they may cause a burn. The springs should also be kept away from combustible material while in use. Operating the springs with battery packs is the safest method of use. Two D cell batteries in series should provide a supply voltage of 3V and a current of up to 3A. Currents in excess of 3A should not be used as they may damage the springs.  Students who progress quickly could be asked to think about how they might speed up the action of the spring both in terms of contracting and re-extending. Faster contraction would be brought about by faster heating and faster re-extension would be brought about by faster cooling.  Faster heating can be achieved with a larger electrical current but this may damage the springs and could be  dangerous to the students. Faster cooling could be achieved by using a desk fan to cool the spring. This could be done in the lab by those teams making good progress.  icon-doc **Helpsheet (Handout)** |
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| **Differentiation** |  | |  |
| **Basic** |  | | **Extension** |
| Lower ability students can simply attach the smart springs to the screw hooks fitted to the arms. They could be asked to describe what happens to the ability of the arm to lift a given mass as the spring is attached to different hooks on the lower part of the arm. |  | | Higher ability students could be asked to use their knowledge of moments to calculate which screw-hook the spring could be fixed to in order to lift a particular mass. Students attempting this task will need to be able to resolve vectors. |
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| **Resources** |  | | **Required files** icon-docicon-pdficon-ppt |
| *Resources required for class*  Several desk fans should be available but kept out of sight of the students until needed.  *Resources required per team*  Wooden ‘arm’ as shown in the diagram on the **Helpsheet (Handout)**. These will need to be constructed in advance of the lesson. This could be done either by the science technician or by the students themselves as part of a joint project with design and technology.   * 1 to 1.5 mm diameter copper or other fairly flexible metal wire. Must be stripped of insulation * A smart spring made from a shape memory alloy such as nitinol * Power supply, leads, crocodile clips * Retort stand * Ammeter * Voltmeter * Sets of slot masses of various sizes |  | | icon-doc Experiment Sheet parts 1 and 2 (Handout)  icon-doc Help sheet (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 a prosthetic foot * ACTIVITY: Materials for a robotic arm   **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 2d, 2e, 4a, 24c, 27d, 35a, 35b * KS4 1.1a,b, 1.2a,b,c, 1.3a,b,c, 2.2d, 2.3b   Design & Technology   * KS3 3b, 3d, 4a   Mathematics   * KS3 1g, 2d, 4l, 6a * KS4 1.1a, 1.3b, 2.1a, 2.2o, 3.2f, 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   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, 2.1a, 2.2a, 3.1a, 5.1f, 5.2a, 5.2b, 5.2c   AQA Engineering   * 3.5   AQA Combined Science: Synergy   * 4.6.1.6, 4.6.1.7   AQA Combined Science: Trilogy   * 6.1.1.2, 6.5.3   Edexcel Combined Science   * 15.3, 15.4, 15.6   Eduqas Combined Science   * 1.1d, 3e   OCR Gateway Science Combined Science A   * P2.3, P5.1   OCR Twenty First Century Science Combined Science B   * P6.3   AQA Physics   * 4.2.1.2, 4.5.3   Edexcel Physics   * 15.1, 15.2, 15.3, 15.4, 15.5, 15.6   Eduqas Physics   * 3.1e   OCR Gateway Science Physics A   * P2.3, P7.1   OCR Twenty First Century Science Physics B   * P6.3   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; * develop a range of practical skills, including the safe use of science equipment; * chemical and material behaviour: structures, properties, uses of materials   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. |
| **Scotland: Curriculum for Excellence**  Science   * SCN 1-15a, SCN 4-16a   Technologies   * TCH 3-01a, TCH 2-12a / 3-12a, TCH 3-13a, TCH 3-13b, TCH 3-14a   Numeracy and Mathematics   * MNU 3-11a, MNU 4-11a, MNU 2-20b | **Wales: National Curriculum**  Science   * KS3 Skills (Communication 2; Planning 4, 5, 6 and 7; Developing 1, 2 and 3) * KS4 Skills (Communication 2; Enquiry and Practical Skills 2 and 3 * 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   KS3 and KS4 Skills  Solve mathematical problems   * develop their skills of estimating and measuring; recognise limitations on the accuracy of data and measurement; select an appropriate degree of accuracy.   KS3 and KS4 Range  Measures and money  read and interpret scales on measuring instruments and understand the degree of accuracy that is possible, or appropriate, for a given purpose |
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| **Assessment opportunities** | | |
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| **Personal, learning & thinking skills (PLTS)** | | |
| * Creative Thinker * Team Worker | | |