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DEVELOPING EDUCATIONAL MATERIALS FOR FORT NELSON HISTORICAL SITE

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## **Abstract**

This project, for the Royal Armouries at Fort Nelson produced an interactive educational science-based site session for students ages eleven to fourteen. The session includes a scavenger hunt, a miniature cannon activity, and a summary section covering the concepts covered. The session appeals to students of varying age, background, and academic ability. Our project enhances the educational resources at Fort Nelson by providing interactive reinforcement of the Key Stage Three curriculum.

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## **Authorship**

All members of our team contributed equally to the overall project. Each member contributed to the background research, the session development, and the written reports.

The team orchestrated the background research by subject. Ero focused on learning techniques and the Key Stage Three curriculum, Rockwell researched museum education, Michael studied the history of artillery and Fort Nelson, and Ari researched methods of collecting feedback. We continued to divide the work throughout our paper: Michael described the differentiation of the session, Rockwell wrote recommendations for the future, Ari completed the data analysis, and Ero edited all written materials. After completion, each group member reread and amended the report.

Every team member contributed to the project both creatively and physically. All ideas for the project developed through group brainstorming and discussion. Each team member contributed to all session materials, including displays, workbooks and mini cannons. The team divided up all work evenly throughout the project. Each member contributed to the research, the session idea development, and the finalised session materials.

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## **Executive Summary**

The Royal Armouries' collection of historic cannon and guns resides in the Fort Nelson historical site in Hampshire, England. The site offers science and history educational sessions for school groups of many different age levels. Although the Fort caters to many ages, before the project, no science-based Key Stage Three site session existed. The creation of a science-based Key Stage Three site session strengthens the educational capacity of Fort Nelson by providing a science-based, hands-on learning experience for students ages eleven to fourteen in the Hampshire area. One educator leads the session, which includes three main parts: the scavenger hunt, the miniature cannon activity, and the summary section. These three parts coincide to reinforce Key Stage Three science concepts and apply science to real life.

The scavenger hunt asks students to find the answers to nine science-based questions relevant to the exhibits on display at Fort Nelson. Specific session displays, designed with students ages eleven to fourteen in mind, correspond to each question. The concepts covered in the signs and questions include gravity, the difference between mass and weight, air resistance, changes of state, simple projectile motion, the storage and use of energy, as well as some directly artillery science related concepts. The students must return to the education room prior to a specific time set by the educator. Once all students return from the scavenger hunt the groups check each other's answers as the educator reviews the answer key aloud, highlighting key concepts and scientific terms from the activity. For each correct answer the students earn one shot in the miniature cannon activity. The scavenger presents many science concepts to the students asking them to think on them to answer questions while they explore the galleries unsupervised.

In the miniature cannon activity student groups aim to shoot a masking tape ball into the ‘castle,’ a medium sized box, set a distance away from the cannon. The cannons shoot utilising spring power. The cannon are designed with a number of variable combinations including three power settings as well as four angle settings. The educator demonstrates proper use of the cannon before students begin the miniature cannon activity. Student groups change variables on their cannon by exchanging the credits they earned from the previous activity. Students must only change one variable at a time to accurately observe and record the results of their changes. The miniature cannon activity gives students the opportunity to engage interactively with science and apply concepts already introduced to a realistic setting.

Once students complete the miniature cannon activity they return to a traditional classroom setting and discuss their findings. Each group describes their best variable combination and explains their reasoning. Next, the educator leads a discussion encompassing all scientific concepts and Key Stage Three units addressed in the previous activities. Students actively participate in the discussion and relate science both to artillery and to real life. The summary section reviews all material presented in an active manner closer to the more student familiar classroom learning style. With this review, students may relate the material from the session to traditional science education in the classroom.

Students participating in the session gain a deep, useable understanding of many science concepts. The students must think critically and actively participate to succeed in the session. The educational site session developed adds another dimension to the Royal Armouries’ education system at Fort Nelson and provides a valuable tool for Key Stage Three schools in the Hampshire area.

## **1. Introduction**

Fort Nelson was built on the 1859 Royal Commission as one of five Portsdown forts to protect the docks of Portsmouth from a potential French land invasion. The Fort was disarmed in 1907 and abandoned in 1950 following its use in World War I and II. The Royal Armouries restored, repurposed, and reopened Fort Nelson in 1995 as the home of their artillery collection. Housing hundreds of big guns and historic cannons, Fort Nelson displays one part of the National Collection of Arms and Armour. Open year-round, free to the public, the Fort hosts live fire demonstrations, costumed guides, video presentations, and an intricate tunnel system for visitors to explore.

The Fort holds hands-on classroom sessions for students to further their education in both science and history. The interactive experience greatly increases student involvement and reinforces key curriculum subjects. Rather than passively experiencing a lecture interactive learning allows students to engage with the material and grasp the concepts through active participation. Studies show that allowing students to interact directly with the material increases comprehension. Studies also show that the interactive presentation of subject matter engages and excites students, spurring them to pursue science further (Wishart and Triggs, 2010).

Under the United Kingdom's education curriculum, students are encouraged to "develop their own identities through an understanding of history at personal, local, national, and international levels" (Qualifications and Curriculum Development Agency [QCDA], 2010). In other words, the students should understand how the information they learn fits into their world and why the world has transformed over time. Therefore, students who experience hands-on learning are able to better relate subjects with their lives and the world around them.

Our project improves education for Key Stage Three students (ages eleven to fourteen) by introducing a creative site session at Fort Nelson that reinforces curriculum subjects. The site session includes hands-on activities and other learning techniques that engage the students in active learning (Bonwell & Eison, 1990). According to Johann Pestalozzi, the founding father of interactive learning, engaging students in the material and allowing them to draw their own conclusions highly increases understanding in the subject matter (Pestalozzi, 1859).

By analysing existing museum exhibits and the Key Stage Three curriculum, we created an educational session that engages students while reinforcing classroom learning. Following the development of the basic session, the session changed to meet the needs of all students within the Key Stage Three level. This differentiation resulted in the creation of a student handout for advanced students, a complete version of all session materials for lower academic levels and struggling students, and how the session may be run indoors under inclement weather. By relating the Key Stage Three curriculum to the collections at Fort Nelson, the session associates artillery science directly to classroom learning and provides learning techniques that are supplementary to general classroom teaching methods. We evaluated organisations with similar educational site sessions including the Boston Museum of Science, the Higgins Armory Museum in Worcester, Massachusetts, the British Museum, and the Royal Armouries' White Tower, to gain an understanding of the learning techniques employed by such organisations in order to discover the best practice in teaching methods.

## **2. Background and Literature Review**

Our project focuses on creating an informational and interesting site session for students ages eleven to fourteen of differing academic levels and abilities. The research required for the project includes three main categories. We first explored the history of Fort Nelson and the history of artillery as background information. We then inquire into museum education as a tool for interactive learning. Finally, we developed a site session based on the Key Stage Three curriculum and interactive classroom learning techniques. This data provides a basic understanding of UK Key Stage Three learning styles and ideas on engaging young teens in science.

### **2.1 History of Fort Nelson**

In the 1860s the British constructed Fort Nelson under Royal commission to defend the Portsmouth docks from a French land invasion (Royal Armouries, 2010). The invasion never occurred and the Fort went unused. It was disarmed in 1907 to house troops and store anti-aircraft munitions. It was fully abandoned following World War II and converted to a museum in 1994. Fort Nelson became the home of the Royal Armouries' historical cannon and artillery collection in 1995 (Royal Armouries, 2010).

### **2.2 Brief history of Artillery**

Through technological advancements, artillery evolved into an invaluable military tool. The invention of gunpowder, in China, spawned the idea of artillery. Artillery started as hand cannons and simple rockets used to defend against Mongol invaders. Eventually, as newer technology developed, people harnessed the power behind gunpowder by containing the expanding gases (Ling, 1947). Gunpowder spread to Western Europe along the Silk Road (Brotton, 2002). Europeans used gunpowder to fuel simple single firing cannons, which

developed into a basic military staple, replacing cavalry and forever changing the face of warfare.

During the Renaissance, technology flourished as scientific development progressed. Through these developments, cannons advanced in range, accuracy, manoeuvrability and power. Leaders recognised the power and effectiveness of artillery and implemented cannons into battle more frequently. The first cannon to include all modern features was the French 75 in 1897. After this cannon's development, artillery design slowed. Recent improvements include adding explosive charges or guidance systems that progress towards the field of rocketry rather than artillery (Dastrup, 1992).

The history of artillery provides a context for the science of our session within the museum. Having a basic understanding of artillery history proved invaluable when communicating with our sponsors and other Royal Armouries staff.

### **2.3 Museum History**

Museums have a long rich history of education and enjoyment. Regardless of purpose, museum exhibits have captivated the interest of visitors and showcased the world's artefacts and principles for thousands of years. Individuals, as far back as the Ancient Greeks, Romans and Egyptians (Alexander, 2008) gathered private collections of historical, religious and beautiful artefacts for worship and enjoyment. It wasn't until the late 17<sup>th</sup> century, however, that private European collectors opened public galleries. Over the last four centuries, museums grew and flourished to become an important part of society and the world (Alexander, 2008).

### **2.4 Museum Education Strategies**

Lecture-based methods of teaching have dominated educational practices for centuries. With the recent interest in interactive learning, however, modern teachers are

supplementing standard lectures with hands-on resources to enhance the educational experience of the students and to provoke critical thinking. Although learning has traditionally been viewed as occurring through lectures, students acquire more knowledge through experience and active learning. “In other words learning is not some abstract experience that can be isolated in a test tube or laboratory but an organic, integrated experience that happens in the real world” (Falk, 2000). Consequently, interactive museum learning enhances the educational value of the information and builds stronger ties to subject material.

Museums, like the Boston Museum of Science, utilise great interactive learning techniques into their education methodology. Aside from providing information in displays, museum employees express their own expertise in a variety of ways throughout the museum (Shortlidge, 2010). Employees use a multitude of active learning aids, such as projectors and hands on exhibits, to further explain and teach information to the visitors. Specialists present information to large groups on various topics from nanotechnology to space flight. These presentations attract visitors and display facts in an interesting and engaging manner. Museum staff often circulates the exhibits, helping to enhance visitor learning and answer any questions (Shortlidge, 2010). By researching interactive learning techniques implemented in other museums, we can adapt our methods. These include student handouts and group discussion sessions, to create an intriguing and educational site session.

## **2.5 Information Gathering Case Study**

Springer Science & Business Media conducted a study in July 2007 about gathering accurate information from Key Stage Three students. The study determined the usefulness of an electronic survey conducted on children of ages eleven through fourteen, while gathering important data for participating organisations (Bamberger, Tal, 2009). In this study, Springer

Science & Business Media surveyed roughly 500 students about their learning experience in a variety of natural history museums. The study utilised several data gathering techniques, including electronic surveys, open-ended questions, and structured group interviews. After analysing the data, Springer Science & Business Media reached the conclusion that combining all of these data collection techniques produces the most accurate and useable results. Each strategy contains benefits and faults, but together the methods balance and provide useable information.

Springer Science & Business Media tested surveys first. Surveys included 25 statements about the museum experience. Students rated each statement according to an agreement scale: strongly agree, agree, not sure, disagree, and strongly disagree. At the end of the survey, Springer Science & Business Media asked an open-ended question to further gauge the student's reaction and the overall success of the museum experience (Bamberger, Tal, 2009). The survey included three sections: subject material, knowledge retained, and entertainment value. The open-ended questions allowed students to give detailed responses while closed questions provided more quantitative data. Springer Science & Business Media found that the questionnaire did not allow students to freely express their opinions. Combined strategies generated better information, by not only incorporating a quick, quantitative questionnaire, but also by allowing students to express themselves with open response questions.

Secondly, Springer Science & Business Media tested interviews. Interviews included both specific and general questions, asking students to describe their time at the museum. Students explained what material they liked and disliked to determine key points of interest and necessary session improvements for the program (Bamberger, Tal, 2009). Unlike questionnaires, interviews allow students to elaborate upon their opinions, providing valuable insight to the conductors of the study. Although interviews do not provide qualitative data



and therefore create problems with analysis, this information gathering technique gives a wider and deeper range of information and provides a more knowledgeable basis for museum changes.

In conclusion, questionnaires provided useful information in areas such as engagement, experience, and relevance and open-ended questions did not provide strong feedback. In general, students responded elaborately on one subject area while neglecting the rest, creating biases and less useful data. Interviews provided extremely valuable data because the interviewer could explain questions more thoroughly and personalise each experience to the specific interviewee. Although interviews provided the most detailed and complete information, each group interview took approximately fifteen to twenty minutes thus making them the least time efficient information gathering method. While interviews produce the most useful data, their time commitment detracts from their efficiency. We used a combination of questionnaires, surveys and interviews to attain the most useful quantitative and detailed information about the session.

## **2.6 Key Stage Three Curriculum Overview**

The Key Stage Three science curriculum spans biology, earth and environmental sciences, waves and physical science. The material pertinent to our study includes unit 7I, 7K, and 8I. Each unit relates to a specific number and letter combination. The number coincides with the students' year while the letter determines the order in which teachers present the units. These units encompass forces, heating and cooling, energy and general scientific investigation (Department for Children, Schools and Families, Science at Key Stage Three, 2010). Each unit splits into sections with sample activities and specific outcomes that students must comprehend along with an estimated timeframe to keep the class on track for the year (Department for Children, Schools and Families, Science at Key Stage Three, 2010).

For example, according to the curriculum, the ‘Forces and their effects’ section should take approximately eight hours to complete. The specific topics include examples such as why objects float, what weight is, and how cars stop. After learning this material, the students should be able to identify a force, use a force meter, and explain their observations of the physical world in basic terms.

The last section of each unit reviews and reinforces previous sections and explores ‘scientific enquiry’. In this way the sections emphasise both hard science and the scientific process. For example, in the ‘Gravity and Space’ section of the curriculum, students learn about how gravity affects different bodies depending on mass and distance, and how recent knowledge changed the way people look at outer space (Department for Children, Schools and Families, Science at Key Stage Three, 2010). By incorporating both branches of the science curriculum, students delve deeper into scientific discovery while also learning scientific facts. In this way, the site session educates students more effectively and relates to all aspects of the curriculum.

The UK Curriculum’s specificity outlines student’s education and forms a basis for our session. By analysing the specific units and applying them to artillery science and Fort Nelson’s exhibits we created a curriculum relevant, educational and entertaining site session.

## **2.7 Learning Strategies for Engaging Young Teens**

Our project must balance educational relevance with entertainment value. Because the curriculum provides an extremely specific timeframe, teachers need affirmation that any site session directly relates to the curriculum before planning a field trip to Fort Nelson. Although the session must relate directly to the curriculum, students must find the material interesting to grasp the educational value of the session. If the subject matter captivates students, they will listen and absorb the material. If the session bores students, they will not pay attention therefore reducing its effectiveness.

Many social scientists have developed methods to engage students in active learning. According to James A. Minstrell (1989), a fundamental understanding of key concepts, within a specific academic arena, provides a basis for further learning; this is especially relevant to the study of physical science. Students between the ages eleven and fourteen do not learn advanced equations to describe the world around them, but have probably moved an object across a surface or witnessed an object falling to the ground. Incorporating personal experience into teaching, as a basis for active learning, enhances the educational process and increases understanding (Bonwell & Eison, 1990). Active learning incorporates discussion, conversation and critical thinking into education instead of teaching by traditional lecture-based methods. Active learning techniques capture the attention of students more effectively and force students to “engage in such higher-order thinking tasks as analysis, synthesis, and evaluation” (Bonwell & Eison, 1990, p. 1).

Hands-on and interactive learning increases students’ interest in science education. Interactive learning splits into two distinct branches, namely, cooperative learning and collaborative learning. In cooperative learning environments, all students work together to gain knowledge, rather than competing against each other. In this learning style the teacher develops specific processes that the group carries out to achieve a predetermined result. According to Spencer Kagan, “the structural approach to cooperative learning is based on the creation, analysis and systematic application of structures, or content-free ways of organising social interaction in the classroom,” which means that cooperative learning allows students to discuss and interact with each other, while still completing a specific goal assigned by the teacher (Panitz, 1999, p. 5).

The United Kingdom education system uses collaborative learning techniques. In a collaborative learning session, students work together with teacher facilitation. Collaborative learning encourages students to actively participate in their own education. Students complete

tasks without focusing on achieving a specific outcome (Panitz, 1999, p. 5). Since groups run their own discussions, collaborative learning environments allow students to experience teamwork in a more realistic manner. To use this method, classes break into smaller groups to complete activities and eventually reconnect to discuss and evaluate findings as a class.

To create a successful site session, we must incorporate both cooperative and collaborative learning. Although allowing small groups to work together on an abstract goal creates the best learning environment, our sessions include a lot of information in a limited timeframe. To balance these techniques, we used collaborative learning to focus each group on their specific task, while still allowing students to work together in a cooperative learning environment.

This project that works with the Royal Armouries Museum to incorporate their exhibits and historical pieces into the predetermined science curriculum, puts hands-on learning at the core of our methodological and educational framework. Johann Pestalozzi developed the basic template for this type of interactive learning in the mid 1800's (Pestalozzi, 1859).

Pestalozzi states, in his book *Pestalozzi and Pestalozzianism*, that direct experience provides a more entertaining and therefore educational learning experience than plain lectures (Barnard & Pestalozzi, 1859). Furthermore, the author opines that encouraging children to ask questions and discover knowledge through curiosity and mistakes leaves a much larger imprint on their minds than passive learning. Also, that students transfer experience to theoretical concepts more easily than they apply textual explanations to conceptual problems. He also articulates that students must observe and understand concepts naturally and that “direct and concrete experience” provides a better background than “book learning.” Lastly, Pestalozzi states that keeping knowledge simple or breaking difficult subject matter into smaller, less complex parts greatly increases understanding (Reese, 2001). By breaking our

session into different activities and allowing students to absorb information at their own pace, the experience holds the students' attention and more effectively educates them.

Benjamin J. Bloom's scholarship also examines and proposes various teaching and learning techniques. He developed "Bloom's taxonomy" (later revised by Anderson and Krathwohl) which broke learning into six 'levels of thinking'. The original taxonomy stated that "learning is a process" (Buehl, 2009, p. 158). Table 1 explains the different steps in the revised taxonomy using literature as an example topic:

Level of thinking	Comprehension self-assessment	Focusing question	Comprehension process
Creating	I have created new knowledge.	How has this author changed what I understand?	Synthesising
Evaluating	I can critically examine this author's message.	How has the author's perspective influenced what he or she tells me?	Inferring
Analysing	I can take my understanding to a deeper level.	How is this similar to (or different from) other material that I've read?	Making connections, Determining importance
Applying	I can use my understanding in some meaningful way.	How can I connect what this author is telling me to understand something better?	Making connections Inferring

Level of thinking	Comprehension self-assessment	Focusing question	Comprehension process
Understanding	I can understand what the author is telling me.	What does this author want me to understand?	Determining importance  Inferring  Creating visual/sensory images
Remembering	I can recall specific details, information, and ideas from this text.	What do I need to remember to make sense of this text?	Determining importance

Figure 1: Taxonomy of Self-Questioning Chart.

Buehl, Doug. (2009). Taxonomy of Self-Questioning Chart. In Doug Buehl, *Classroom strategies for interactive learning*. Newark, Delaware: International Reading Association.

Even though Bloom’s Taxonomy has traditionally been utilised as a tool in language arts and literature studies, it can also be applied to other academic disciplines. By basing our activities on these ‘levels of thinking’ (Buehl, 2009, p. 158) we can insure our site’s effectiveness as an educational tool. Since our site session runs for two hours, the information must accurately and quickly explain the science topics. Using Bloom’s taxonomy increases learning while reducing repetition and keeps our session within the timeframe specified by the Royal Armouries. Doug Buehl suggests educators should use this chart for students to self-evaluate and to spark “think-aloud[s]” (Buehl, 2009, p. 157) or discussions. Discussing why, how, and what a scientific principle means in real terms, ensures that children absorb more information and actively participate in the session.

According to Buehl, basing science education on “natural curiosity” (Buehl, 2009, p. 153) produces a good science-learning environment. He states that although all people find

the world around them intriguing, terminology and sophistication form a barrier between science with its difficult terminology and student's "questions about 'real-life' processes." By removing this barrier, or applying student's questions to the material, science becomes less intimidating and more interesting to learn. Although the site session follows a standard format, test groups reveal what the average eleven to fourteen year-old student finds interesting. Holding a test session allows us to personalise the final site session and edit any significant problems with the entire process.

Part of our project includes creating differentiated instructions so the site session applies to many different academic levels. We developed edited session materials to accommodate for learning disabilities. According to our sponsor, who is a certified teacher for all academic levels, breaking lessons into smaller time blocks allows students with learning disabilities to comprehend the material to a greater degree. By changing subjects and activities over the course of the allotted time, students do not concentrate on one subject for too long. Breaking up large blocks of time into many intriguing activities allows children with limited attention spans to concentrate on the activities and successfully experience the session (Martin-Smith, 2010). Along with splitting the session into smaller, more active pieces, the session balances hands-on activities with discussion; this ultimately reinforces the materials without overtaxing students' attention spans. Although this research applies specifically to students with learning disabilities, it relates to all levels of students. Keeping the session in motion helps students engage in interesting material without forcing them to concentrate on one task for too long and makes the session both educational and entertaining.

## **2.8 Conclusion**

In conclusion, the session splits into three sections based on different types of active learning. Researching hands-on and active learning techniques provided insight into the learning process of Key Stage Three students and helped develop the specific activities

within the session like the miniature cannon activity. By applying interactive learning methods, the session intrigues and engages students while still providing curriculum-based learning. Incorporating such interactive learning techniques into our session allowed for the creation of the scavenger hunt activity. Students explore the museum and interact with exhibits in an organised but unguided fashion. Even though our session has a timeline and schedule, the students are encouraged to investigate and explore the area. By applying museum-learning techniques to the UK Key Stage Three curriculum, the session balances both educational value and entertainment, and ultimately works to enhance students' learning and appreciation of inquiry.



### **3. Methodological Approach and Tools**

#### **3.1 Development of Session Education Materials**

To create a science based site session for Key Stage Three students visiting Fort Nelson, we developed a list of standards based on the Key Stage Three curriculum and the exhibits at the Fort. We split the session into separate interactive activities based on the selected exhibits and curriculum units.

First, we created a set of science-based questions formatted into an artillery science scavenger hunt. To aid students in the scavenger hunt, we developed handouts with maps and alternate signs for the selected exhibits (See Appendix D). The session signs contain less text than the original museum signs (See Appendix L). Along with holding less text, the session signs take the students' educational level into account by using simplified language and breaking text into smaller segments. The session signs also focus on the science of the exhibits rather than the history behind them. The session signs contain large, eye-catching diagrams and titles along with concise scientific concepts that pertain to the scavenger hunt questions. To assist teachers and museum staff, answer keys accompany the student handouts. In this way, the session administrators guide the session as students grade each other's scavenger hunt answers.

In the next activity, students shoot miniature spring powered cannons. Our team prototyped the spring cannons to suit the needs of the session and the safety requirements specified by the Royal Armouries. The cannons contain three variable power settings and five angle settings that give students fifteen different combinations to test. The groups receive one shot of the cannon for each correct answer from the scavenger hunt. Students may trade their shots to change variables on the cannon. Students must launch the projectile

into a 'castle' and record their observations. Students must think critically about each change and how adjusting the cannon affects the path of the projectile.

After students finish their shots, the groups reconvene for the summary session. The session educator leads a discussion that relates the questions from the scavenger hunt to the miniature cannon activity and reinforces all scientific concepts reviewed in the session. After discussing the results of the miniature cannon activity, each group takes one final shot with their best combination of variables. Students then present how and why they chose a specific angle and power setting. In this way, students must thoroughly understand the concepts behind the miniature cannon activity. The session provides students with real world examples of topics relevant to the curriculum while they participate in an entertaining hands-on activity.

### **3.2 Test and Evaluation of the Session**

Two classes of students tested the session to determine its effectiveness and identify possible problems. Each class divided into three groups and participated in the session accompanied by members of our team. In this way, we gained key insight into the session timeframe and were able to witness any faults in the activities through observation of the students during the session. At the conclusion of the session we distributed questionnaires to the participating students and teachers (See Appendixes P, Q). The questionnaires asked a variety of questions pertaining to the specific activities and the students' experience of the session as a whole. To determine the success of the session and finalise the materials, we evaluated all of the teacher and student responses and adapted the session to reflect the findings (See Appendixes R, S, and T).

### **3.3 Adaptation of the Session**

The adaptation of all session materials took into account results from teacher, student, and educator feedback; these perspectives clarified which sections of the session needed editing. After finalising the session, all of the materials created received the Fort Nelson and Royal Armouries branding.

Some session problems included typographical and labelling errors. For instance, the workbooks contained two different questions with the same title. The signs required additional clarification where students found them confusing. For example, the edited 'Mass Matters' sign contains scientific data that contradicts the actual exhibit display because the original displays concentrate on history and contain some scientific errors. Navigating Fort Nelson challenged students during the scavenger hunt, even with the original map of the Fort, as it did not clearly show the format of the galleries. To alleviate confusion, another map specifically outlining the convoluted pathway through the galleries developed. The materials for the miniature cannon activity generated numerous problems as we received the correct spring after the session date. As a result, the test session cannons used hand wound coat hangers for springs. The springs powered the cannons but deformed easily and caused inconsistencies in the power of the cannon shots. Students understood the concept behind choosing the correct combination of variables but could not witness the results because the cannons changed with every launch. The final cannon design contains professionally wound springs, resulting in consistent power settings. Along with inconsistent cannons, the original reward system confused students and educators. The new reward system clearly outlines the reward system and allows the session educator to monitor all groups easily.

The original educator materials briefly explained the session and outlined key points to focus the discussion. The finalised version of the materials clarifies and details the session

aims and goals for the educator (See Appendix A). The new materials thoroughly explain all key science concepts for a non-specialist. Along with enhancing the educator materials for ease of use, we developed an additional sign that demonstrates the proper, safe use of the miniature cannons and shows students the layout of the scavenger hunt displays (See Appendix L1). The final version of the materials describes the session step-by-step and requires no previous experience.

### **3.4 Differentiation of the Session**

We created separate session materials for a number of circumstances and to suit the needs of students of all academic levels within Key Stage Three. To fulfil this requirement, we designed alternate versions of the session for struggling students and students with learning disabilities (See Appendixes F, M). The session also included more material to challenge older and more advanced students who fall in the Key Stage Three level. Following the changes made to account for varying academic abilities of the students, we adapted all session materials to function in periods of inclement weather.

To educate children of lower academic abilities and accommodate possible learning disabilities, the format of the session materials changed significantly from the original. The session displays contain simpler words and breaks the important information into smaller segments (See Appendix M). By changing the display format, the signs ease comprehension for students with many commonplace learning disabilities. Along with editing the session displays, the student workbook format also changed. Unlike the original workbooks, which contained short answer questions, the differentiated workbooks ask closed procedure and multiple-choice questions (See Appendix F). The wordings of all statements on the student workbooks changed to match the signs for the benefit of struggling students. The new question format allows students with learning disabilities, who may have trouble writing out

their thoughts, to answer questions in a clear-cut method. Although the question format changed, all scientific material stayed the same to provide lower level students the same experience as older or more advanced Key Stage Three children.

We developed an additional student worksheet to accommodate students of higher academic ability and those students particularly interested in science (See Appendix N). This worksheet follows the scavenger hunt activity and provides students who finish the activity early with a productive and scientific activity to work on while they wait. The worksheet focuses on projectile motion. Students must sketch the path they believe the projectile will follow given a certain set of conditions. The worksheet also asks students to draw reaction forces on a diagram which is a concept not traditionally introduced at the Key Stage Three education level. To help the students with this difficult concept, the worksheet references information that the students learned during the scavenger hunt activity. The worksheet also asks where the miniature cannons, used in the upcoming activity, store energy. Along with questions about energy, the worksheet also questions the material and size of the projectile used in the miniature cannon activity. By referencing both the scavenger hunt activity and the miniature cannon activity, the advanced worksheet further reinforces the application of scientific facts to real artillery science. The worksheet compels students to think critically and apply scientific concepts to the miniature cannon activity.

Museum site sessions occur all year round. Schools must schedule field trips far in advance. To allow the session to function under inclement weather, the entire session must take place indoors (See Appendixes H, J). To maximise the efficiency of the indoor session, the scavenger hunt takes place within the galleries so the students need not walk far; walking between the galleries and other parts of the museum creates new dangers within the session because the pathway contains a set of slick stone stairs. To edit the session for weather, session displays that originally related to exhibits throughout Artillery Hall and the ramparts

required relocation to exhibits within the galleries. The new session materials include a guide that indicates which signs belong with which exhibit. All other session activities will take place within the education room and therefore required no further changes.

### 3.5 Project Timetable

The timetable for our project shows the duration of each project task. Many of the restrictions placed on our timetable occurred because of changes within the Royal Armouries. The original sponsors left at the end of our fifth week and a new sponsor took over. As a result, our overall timetable for developing and testing the session condensed into the first five weeks. The staff changes within the Royal Armouries also pushed up the date of our test session to the middle of the third week. To accommodate for this, all prototype session materials developed extremely quickly. After completing our test session, all of the collected feedback required analysis, which spanned the rest of week three and flowed into session finalisation during week four. We incorporated feedback and finalised the session materials through the end of the fifth week to deliver the results to our sponsors prior to their departure. Following the completion of all session materials, we worked to compile our final report, finish cannon construction and created directions on how to replicate our design. This timetable is displayed in Table 1 below.

<b>Tasks:</b>	<b>Week 1</b>	<b>Week 2</b>	<b>Week 3</b>	<b>Week 4</b>	<b>Week 5</b>	<b>Week 6</b>	<b>Week 7</b>
<b>Prototyping of the session</b>	<b>X</b>	<b>X</b>	<b>X</b>				
<b>Test and evaluation</b>			<b>X</b>	<b>X</b>			
<b>Adaptation and finalisation</b>			<b>X</b>	<b>X</b>	<b>X</b>		
<b>Differentiation</b>				<b>X</b>	<b>X</b>		

<b>of the session</b>							
<b>Writing the final report and the creation of additional materials</b>						<b>X</b>	<b>X</b>

Figure 2: Timetable of Project Tasks.

### 3.6 Conclusion

The creation of a science-based site session for the Royal Armouries at Fort Nelson took many steps, much work, plenty of evaluations, and a long list of changes. The development of the session required an in-depth understanding of the UK Key Stage Three curriculum and a comprehension of how to apply topics that are pertinent to not only the students learning level, but also the collections at Fort Nelson. Creating a session that balanced both student enjoyment and educational value proved challenging because of the strict curriculum guidelines. The evaluation of the session showed faults in the prototype and exposed weak areas that required editing for smooth session operation. The changes made to the session varied from typographical corrections to incorporating previously non-existent information. The differentiated versions of the session proved challenging to create because proper word selection required much thought, time and input from education professionals (Martin-Smith & Preece, 2010). The additional worksheet for students also took time to create as it needed to challenge students and urge them to draw concepts from the scavenger hunt and apply them to the miniature cannon activity. The project timetable proved challenging because of rigid deadlines and changing Royal Armouries staff. All finalised session materials contain the branding of the Royal Armouies and Fort Nelson and took much effort to suit the needs therein.

## **4. Findings and Results**

### **4.1 Introduction to Findings**

To develop education materials for Fort Nelson, we compiled two separate types of findings. Firstly, we researched exhibits at Fort Nelson Historical Site and the Key Stage Three curriculum to compile a list of relevant and interesting material. We also researched different interactive learning techniques as background for session ideas. Secondly, we created a session based on these findings and tested it to produce feedback on the session quality. Our sponsor handpicked the participating students from Key Stage Three Hampshire schools and science clubs. Students and teachers from the prototype session filled out questionnaires and provided reliable feedback to create a basis for session adaptations and finalisation.

### **4.2 Creating Session Basis**

#### **4.2.1 Session Basis Overview**

The first step in creating a site session for Fort Nelson consisted of constructing an informational basis for the educational portion of the session. By comparing the Key Stage Three curriculum to the existing exhibits at the Fort, the session basis relates to both artillery and Key Stage Three classroom learning. Findings showed that the four main Key Stage Three subject areas that relate to the museum's collections were units 7I, 7K, 8I, and 9M (Department for Children, Schools and Families, Science at Key Stage Three, 2010).

#### **4.2.2 Unit 7I: Energy Resources**

Unit 7I covers energy resources. Research states that students ages eleven to fourteen learn concepts of energy through fuel and food (Department for Children, Schools and Families, Science at Key Stage Three, 2010). The sample site session demonstrated that asking students to relate gunpowder to energy allowed them to think critically about their prior knowledge of energy and relate it to a cannon firing.



#### **4.2.3 Unit 7K: Forces and their Effects**

Unit 7K encompasses forces and their effects (Department for Children, Schools and Families, Science at Key Stage Three, 2010). Analysis showed that friction, air resistance, and gravity hold the most relevance to Fort Nelson and the Key Stage Three curriculum. Research shows that students ages eleven to fourteen understand the basic concepts of forces and unit 7K requires that students can identify forces and their effects in everyday life. By creating a link between the artillery at Fort Nelson and forces that students have learned about in the classroom, science becomes more concrete and students who experience the session realise that science has real world applications. Our sponsor informed us that many UK students find science boring and extremely difficult (Martin-Smith, 2010). By presenting the notion of forces in an appealing and easily understandable manner, the site session shows science in a new light.

#### **4.2.4 Unit 8I: Heating and Cooling**

The third unit, 8I, covers heating and cooling. Touring the museum showed that the forge contained the only interactive technology at Fort Nelson. By incorporating this exhibit into the session, students experience more hands-on learning without expanding the session timeframe. Results from our sample session showed that relating heating and cooling to forging cannons reinforces Key Stage Three subjects; these subject areas include change of state, and its applications to artillery. By choosing heating and cooling for a section of the session's informational basis, the Key Stage Three subjects covered expand from focusing on primarily physics topics to including chemistry and reactions. Incorporating both physics and chemistry topics diversifies the session and breaks the informational basis into sections, this inevitably triggers new thought processes in students and allows them breaks that do not detract from the session's educational value.

#### **4.2.5 Unit 9M: Investigating Scientific Questions**

9M, the final unit, investigates scientific questions. Findings show that topics such as 9M, which cover more abstract scientific concepts, do not appear on exams. Therefore, teachers who are operating under an extremely strict timeframe, use the extra time to reinforce more hard science instead of explaining less concrete scientific methods (Martin-Smith, 2010). By incorporating the scientific method and general science inquiry into the session, students will not only review past units but also learn new information. Findings show that by covering topics less emphasised by the curriculum, our session appeals to teachers and provides more intellectually stimulating information for the students (See Appendix P2, R).

### **4.3 Development of Session Activities**

#### **4.3.1 Session Format**

Requirements of our site session included entertaining Key Stage Three students, providing a valuable educational experience, and allowing the students to explore the museum in a controlled but free roaming environment. To accommodate these requirements, the session split into three sections: the scavenger hunt, the mini cannon activity, and the discussion session. By incorporating three separate activities into the session, students experience science in a multitude of ways and focus on each portion individually. Findings show that organising the session into separate tasks enables students to concentrate longer and absorb more information (Martin-Smith, 2010). Although breaking up learning into sections proves to be most effective (Martin-Smith, 2010), the session must still retain an element of cohesiveness. By rewarding students with more shots in the mini cannon activity, students strive to answer the scientific questions correctly; this element reinforces the session's educational value.

### **4.3.2 Scavenger Hunt**

The first activity in the session, the scavenger hunt, covers the exploration portion of the session. By roaming the galleries, Artillery Hall, and the ramparts in small groups the students experience the collections without a guided tour. Along with allowing the students to explore, the scavenger hunt provides an extra educational element where students search the exhibits for specialised displays. These signs specifically answer questions provided on the workbook that is given to each student group at the beginning of the session (See Appendix L). Students focus on specific collections pointed out in the scavenger hunt while still retaining an element of freedom to experience other interesting material. The displays created for the session utilise the key principles of artillery and relate them to specific science concepts from the Key Stage Three curriculum. By spreading the displays throughout the museum, students process the signs one concept at a time and apply the information to the corresponding question on the workbook.

### **4.3.3 Mini Cannon Activity**

The miniature cannon activity encourages students to apply scientific concepts and principles from the previous activity into a successful cannon firing. To shoot the cannon into the castle, students must draw information from the scavenger hunt to pick the best launch setting. The cannons include both variable angle and variable power settings. Students must think critically about changing the cannon settings to successfully launch their projectile into the ‘castle.’ The castle consists of a medium sized box with high walls. To successfully shoot the cannonball into the castle, students must be conscious of the castle’s shape. The high walls force students to acknowledge the trajectory of their projectiles and relate their background information of projectile motion. If the ammo does not arc high enough, the ball will not penetrate the castle wall. By incorporating collaborative learning (Panitz, 1999, p. 5) into our session, students experience a realistic scientific process and learn about the scientific method. The knowledge reinforced by the session improves

understanding of forces and angles and allows students to grasp the basics of projectile motion through successfully firing a cannonball into the ‘castle.’ Even groups who did not manage to ‘invade the castle’ understood the basic principles and could explain why they chose a specific power setting and angle. The major focus of the activity is on the change of variables and the scientific process. Students change one variable at a time in order to see the effect of what they altered and they record every change. Through this process, students create a guide that summarises everything they’ve learned and can be easily reviewed for further reinforcement of the scientific concepts.

#### **4.3.4 Discussion Session**

Throughout the scavenger hunt and mini cannon activity, students learn actively through hands-on experience and scientific discovery. Prior teachers who took students to Fort Nelson requested more connectivity between site sessions and the UK curriculum (Preece, 2010). They also asked that all topics covered within the session relate back to classroom learning. By incorporating a discussion-based summary into the session, students must think critically about the science they experienced during other session activities. The summary session brings together all the hands-on and interactive activities and reinforces the concepts in a traditional classroom method. After observing the prototype session, findings show that the students do learn throughout the session and can explain their observations in simple terms (See Appendixes R1, S). By analysing the information garnered throughout the session, students reinforce important concepts and relate them to their in-class learning.

### **4.4 Methods of Collecting Feedback**

#### **4.4.1 Information Gathering Techniques Overview**

Informal interviews and questionnaires followed the prototype session to collect teacher and student feedback. During the informal interviews, teachers and students

expressed their opinions through the session and mentioned which portions were interesting and which were confusing.

After conducting the session, the educator provided feedback on what portions of the teaching materials needed extension and shared other changes that would improve the session. Having a discussion with the educator after the test session crystallised what portions of the session were unclear or needed further explanation and emphasis.

Upon completion of the session, teachers and students filled out questionnaires as a more formal information gathering technique (See Appendixes P, Q). The questionnaires provided more concrete data that allowed further analysis of the session's strengths and weaknesses. The student questionnaires focused on the difficulty of the session and their experience throughout the session (see Appendix P). The teacher questionnaires focused on how effectively the session educated the students, as well as what adaptations could improve the educational content and curriculum relevance of the session (see Appendix Q). Both questionnaires consisted of two parts: a rating section and a short answer section. In the rating section, students and teachers selected a number between one and six stating their opinions about the session. For instance, students ranked how difficult they thought the exhibits in the scavenger hunt were to find throughout the museum. Most students stated that finding the signs was a 3 out of 6 difficult level, meaning that finding the signs provided students with a challenge without hindering the educational value of the session (See Appendix R1). The short answer section consisted of open-ended questions with space for brief but important answers. In this section, teachers and students expressed their opinions on the session in detail, determining the quality and success of the entire session. Most students and teachers further expressed their opinions at the end of the questionnaire, suggesting improvements for future groups. The suggestions predominately pertained to session

materials such as the maps and session displays, and to clarifying the science facts learned or reinforced during the session like light travels faster than sound.

The responses generated through the questionnaires and the qualitative opinions gathered through the informal interviews achieved a balance of simple analysis and in-depth explanation. In this way, students and teachers expressed their opinions of the session and provided useable and informative data (see Appendices P and Q). Together this information produced an excellent picture of the necessary session adaptations and of how well the session actually functioned.

#### **4.4.2 Reviewing Group Observations**

Throughout the session, our team aided and observed the student groups. During the scavenger hunt activity at least one member of our team guided each student group. We served as their chaperones through the Fort and also observed any issues with the session; when necessary we provided some guidance for struggling students to keep the session flowing. Acting as guides gave a unique insight into the dynamics of each student group and into how students handled the session.

Students had little difficulty locating specialised scavenger hunt displays. Navigating among the three sections of the Fort containing scavenger hunt clues (the Galleries, the Ramparts, and Artillery Hall) however, proved difficult. Another navigational problem occurred within the Galleries because they fork and continue in both directions. The entry to one portion of galleries caused problems because it is partially concealed behind a large sign.

After observing the entire session, specific group dynamics surfaced and repeated. For instance, the predominantly female student groups focused solely on answering the questions within their workbook, whereas male student groups tended to explore the Fort and experience the artillery on display. Because different groups toured the site at different rates,

groups finished the scavenger hunt at drastically different times. Although students completed their work at different rates, no team skipped questions or left portions of the workbook blank. Each group successfully completed all session activities.

Along with navigational and group dynamic issues, the original displays throughout Fort Nelson significantly complicated the scavenger hunt. Some signs throughout the museum express inaccurate information. For instance, one question in our session focused on the difference between mass and weight. On the original museum display, mass and weight were mislabelled. Signage errors complicated already intellectually challenging questions and confused most students.

During the mini cannon activity, we aided students with any technological issues created by the cannons. Along with technical support, we witnessed how students completed the activity and transferred the information from the scavenger hunt to the interactive cannon launching; this provided important data for improving the session. Throughout the mini cannon activity, students stayed engaged because of the unique balance of entertainment and scientific experimentation. Although the session entertained students, frustration and confusion ensued when aspects of the activities failed or functioned incorrectly. For instance, the mini cannons built for the sample session used hand wound springs created from coat hangers because the proper springs arrived after the date of the test session. The hand wound springs worked, but deformed easily and drastically changed the outcomes of the cannon activity. This problem was expected, but still caused significant issues throughout the mini cannon activity.

Along with faulty springs, the scavenger hunt rewards system confused students and teachers. Only one team understood the rewards system without further explanation. The educator attempted to monitor the rewards system, but because it awarded either a shot or

change of variable for each correct response, complications arose. For instance, each shot included at least one change of variable and therefore used multiple ‘points’ from the scavenger hunt. Students took extra shots and changed their cannons more than the instructions allowed. The rules for cannon placement covered change of power and angle, but did not specify whether moving the cannon around was allowed. Students added other variables into their scientific process by changing the distance between the cannon and the castle but did not record their findings.

During the summary section, students gathered as a class to discuss the concepts discovered in the scavenger hunt and applied in the mini cannon activity. Observation showed that this section reinforced scientific concepts from the previous activities and applied the science from the session to classroom learning and real life.

#### **4.4.3 Reviewing Session Educator Comments**

The educator commented on many aspects of the activity. The comments correlated to each specific session activity and reinforced many previous observations. The educator’s notes mentioned introducing the students to Fort Nelson and the Royal Armouries, but provided no set introduction. The educator’s feedback suggested developing supplementary worksheets for groups that finish early or for more advanced classes; comments relating to editing the existing session materials were also included. During the session, the educator noticed three errors on the session workbooks that confused the participating students. The educator also mentioned that although the educator’s materials explained a vague grading system for the scavenger hunt questions, they did not outline a specific grading system. The teaching materials developed for the session covered only the basic information for this activity. New teaching materials were suggested to supplement the discussion so a non-specialist could understand and correctly oversee the discussion section. In the new teaching



materials, for instance, important science topics contained explanations and brief overviews for educators unfamiliar with the subject.

## **4.5 Analysing Survey Results**

By formatting the questionnaire results into a single document, the responses provided clear and qualitative results that outlined the entire session and produced much useful feedback (See Appendixes R, S, and T). The responses, along with statistics such as averages and medians, follow this document in the attached appendices. Along with statistics and quantitative data, qualitative analysis clarifies the short answer responses.

### **4.5.1 Student Questionnaire**

#### **How difficult were the exhibits within the scavenger hunt to find?**

The question provided information on the layout of the scavenger hunt displays. If students rated the difficulty too high then the sign placement must change to accommodate for the timeframe and the students' ease of use. If they rated the difficulty too low, the signs should be made less obvious to enhance the challenge of the scavenger hunt. Students ranked the difficulty of finding the session signs a 3 on a scale of 1 to 6 meaning that finding the signs did not pose too significant of a challenge for students (See Appendix R1). The rating confirms that sign placement did not affect the student's responses; students did have to search for signs but the challenge did not hinder the scavenger hunt's educational. When developing the finalised session materials, no changes in sign placement occurred except those for the inclement weather version of the session.

#### **How hard were the questions in the scavenger hunt?**

The question above illustrates the difficulty of the scavenger hunt questions. If students responded that the questions required too much contemplation and took too much time, then the workbooks and signs must change to better explain the concepts. If the

responses stated that the scavenger hunt questions did not challenge them intellectually, then signs and workbooks must delve into more advanced material to make students think critically and further explore the science of artillery. On a scale of one to six, the two sample groups averaged a 3.1 difficulty rating (See Appendix R1). This means that participating students found the questions slightly simpler than planned. Through further analysis, this rating complies with the sample groups of students, who were selected from science clubs and advanced Key Stage Three classes. They could therefore understand more scientific concepts than other children of ages eleven through fourteen. To accommodate for varied academic ability, a workbook was developed to challenge students along with an entire set of session materials created for students of lower academic ability or with learning disabilities.

#### **How hard was it to get the ball in the castle?**

The student responses outlined the entertainment value and difficulty of the miniature cannon activity. A high rating would mean that the challenge of getting the projectile in the 'castle' proved easy and needed augmentation. A low rating would mean that the challenge presented by the 'castle' proved too difficult and students could not achieve the desired result. The average response ranked 4.5 on a scale of one to six (See Appendix R1). The first and second student groups' averages did not coincide. The first group placed the miniature cannon activities' difficulty at 5.3 while the second group's average fell at 3.5. The inconsistency of responses follows the inconsistency in the cannons themselves; this was an expected problem with the prototype session. Student groups from the first test group could not fire their cannons successfully, while the second set of students had a much higher success rate. Until the activity includes consistent spring cannons, the feedback cannot produce useable data on the difficulty level of the activity.

#### **How much did the summary session help you understand the science behind artillery?**

Responses to this question explained how much information students learned and retained about each topic. Unlike questions pertaining to session difficulty, a six out of six expresses the desired result. A six out of six rating would show that students completely comprehended and retained all of the session information. Depending on the actual score, the session materials and subject matter will be modified to explain artillery science in an understandable manner. The average score for both groups ranked at 4.1, with the first group averaging 4.7 and the second averaging 3.3 (See Appendix R1). The first group, which consisted of older and more advanced students, thoroughly grasped the material and greatly benefited from the session. To improve the amount of learning and retention in the analysis section, future educators should emphasise the science concepts and reinforce the information that students already discovered throughout the session.

**How many scavenger hunt questions did your group answer correctly?**

This question polled the difficulty of the scavenger hunt questions in a quantitative manner. No group answered more than 2 of the 9 questions wrong, but only 4 out of 6 groups answered all the questions correctly (See Appendix R1). The answers to this question show that few groups had trouble with the questions and that the questions could be a bit more challenging. Since the students in the groups had a background in science, it is possible that students that did not have a science background would have struggled more in this activity.

**Did your group get the ball in the castle? How many changes did it take?**

This question showed the level of difficulty of the miniature cannon activity in both a quantitative and qualitative manner. Students could write exactly how many times they succeeded in the activity and explain why it was difficult or why they had problems. Out of the six groups total, two groups did not get the ball into the castle while four groups

succeeded (See Appendix R1). This question does not provide accurate data until the session includes the finalised cannons.

**Was there any part of the session that was confusing? Which part?**

This question gave students the opportunity to freely express any complaints about the session. For instance, most students pointed out the inconsistent cannons, the poor map, and the wording of some session displays. The students tended to mention the obvious problems with the session such as typos and inconsistent cannons (See Appendix S). These problems were all adjusted for the finalised site session materials.

**4.5.2 Teacher Questionnaire**

**How effective was your time at Fort Nelson in educating your students?**

This question pertained to both the educational value and timeframe of the session. By asking the teacher whether the session was worth their students' time, the feedback covers a broad spectrum of information. Because the Key Stage Three curriculum contains such a specific timeframe, teachers must carefully plan school outings and any trip must directly coincide with the curriculum. By gauging how effectively the session further educated students in a specific timeframe, we can determine whether or not other teachers would allow students to participate in the session. The teachers gave ratings of 4 and 5 to this question (See Appendix R2). The high rating shows that the students learned in an effective manner while at the Fort Nelson site session.

**How enjoyable was the session for your students?**

Since teachers work with their students most of the day, they provide a unique insight into not only how much the students learned, but also into how much fun they are having. The session must balance fun and education to keep students interested in science and to run as a successful site session. Both teachers gave high ratings of 5 and 6 showing that the

students had a lot of fun during the session (See Appendix R2). One of the project goals stated that students should enjoy learning during the session, and, according to the teachers, students both enjoyed the session and reviewed valuable science subjects.

### **How effective was the scavenger hunt at reinforcing scientific facts for your students?**

Although entertainment and fun adds another dimension to the session, no museum education session runs successfully without teaching students and reinforcing classroom learning. To determine how effectively the session educated participating students, teachers gauged the educational value on a scale of one to six. Ideally, the educational value of the session would reach a six out of six. If teachers rated the educational value of the session too low, questions must change to more clearly emphasise scientific facts. The teachers rated the educational value of the session at 3.75, almost exactly in the middle of the one to six rating system (See Appendix R2). The teachers thought that the scavenger hunt entertained students but did not seriously reinforce science learning. To increase educational value, the finalised session materials delve further into science and clearly emphasise curriculum science topics.

### **How effective was the mini cannon shooting activity at getting students to understand specific principles?**

Feedback from this question gauges the educational value of the miniature cannon activity. By polling the teachers on how effectively this activity educated and engaged students in science we can determine whether or not the session successfully fulfilled its purpose. As stated above, a six out of six rating means that the mini cannon activity completely educated students on artillery science and successfully reinforced all of the reviewed scientific concepts. Teachers liked the miniature cannon activity because students needed to adjust the cannons variables to succeed; this required critical thinking and application of classroom learning to real life. Teachers rated the activity a 4.5 out of six (See

Appendix R2). Once the cannons fire consistently and accurately display the scientific principles, effectiveness ratings should rise.

### **How well did the summary section combine the ideas throughout the session?**

While designing the session, our sponsors stated that teachers visiting Fort Nelson and participating in educational site sessions requested some sort of review that reinforces the learning and further explains the information learned. After completing the two hands on science activities, students review and discuss everything they've learned in the summary section we created. To gauge the summary session's effectiveness and learn whether or not it fulfilled teacher's wishes, we asked participating teachers their opinions. Teachers ranked the summary section's effectiveness a 3.75 out of 6, meaning that although the concept of a summary section seems highly educational, further organisation would greatly improve its educational value (See Appendix R2). The structure of the summary section depends on each individual group of students and their interest in the material. By allowing the session educator to personalise the section, participating students gain a better grasp of the material and the summary session educates more effectively.

### **What science concepts would you like to be more emphasised in the session?**

This question allows teachers to express their opinions on the subject matter covered in the session. Teachers work with the Key Stage Three curriculum constantly and know which units require more emphasis. By incorporating teacher input on the subject matter, the session further caters to the Key Stage Three curriculum and therefore attracts more classes to Fort Nelson. The first teacher requested that mini cannon variables must only change one at a time, to show the exact effects that each variable change cause. By changing the firing procedure in the finalised session, students now must observe every change of variable and gain a better understanding of basic projectile motion (See Appendix T). The second teacher requested more questions about higher-level physics, making the session more suitable for

KS4 (See Appendix T). Although creating a Key Stage 4 session did not fall into our project bounds, the session easily adapts to higher level science and could produce a similar session for more advanced students.

**What concepts could use more time?**

Asking this question allows teachers to provide valuable insight into the curriculum. As previously stated, teachers understand their students and the Key Stage Three education system. This experience provides important information on the importance of specific curriculum units. The first teacher requested a larger focus on mass and weight because the original displays did not significantly cover the material (See Appendix T). The finalised session material contains better wording so that the students better grasp the science concepts. The second teacher mentioned speed of light and sound (See Appendix T). Although these science subjects do not currently relate to the exhibits within Fort Nelson, they do relate to cannon firing and the observations students could make in a real demonstration. These concepts could be included in the discussion section after witnessing a live cannon firing.

**What concept in the session requires the most significant change in presentation? What can you recommend?**

Like the other questions pertaining to session subject matter, this question allowed teachers to express any concerns about the session or any suggestions they think would improve the session's quality. As previously stated, teachers thoroughly understand the curriculum and what the students learn through the year, providing a unique insight into Key Stage Three learning. The teachers mentioned that displaying an actual projectile's trajectory would further explain and illustrate the scientific concepts (See Appendix T). When developing supplementary session materials for advanced students, we developed a worksheet focusing specifically on projectiles and how changing variables changes the trajectory. The teachers also mentioned that the explanations for the questions were often too direct. Because the participating students were handpicked from science clubs and advanced

classes we decided to develop extra handouts with less direct questions that spawn critical thinking for these more advanced students.

**What materials for pre or post visit would make the session more effective for your students?**

Other site session in existence at Fort Nelson provide teachers with pre and post visit materials to further reinforce scientific concepts and review the relevant coursework before students arrive at the Fort. This question determined whether such materials must supplement the session, but both teachers stated that pre and post visit materials were unnecessary (See Appendix T).

**Would you recommend this session to other teachers?**

This question allowed teachers to express their overall opinion of the session. Both teachers emphatically expressed that the session both taught and entertained students successfully and they would highly recommend the session to their colleagues (See Appendix T). This result shows that the session successfully educates students and advances the educational tools at Fort Nelson. This result states that the test session succeeded and provides a great opportunity for Fort Nelson and Key Stage Three classes in the Hampshire area.

## **4.6 Adaptations**

Analysis provided a list of changes to improve our prototype session by enhancing the students' learning experiences. To solve the navigational issue with the fork in the gallery, we created a secondary map for the student workbook that clearly marked the gallery rooms. To adapt the scavenger hunt, session displays now stand alone and do not rely on existing museum signage. Also, minor wording changed on all signs to clarify the questions. For instance, signs no longer reference exhibits using terminology such as 'this cannon.' The student workbooks no longer contain typographical errors and all questions clearly pertain to their corresponding session display. The answer keys changed accordingly and highlighted



keywords that characterise a fully correct answer (See Appendixes E, G, I, K). For instance, the heating and cooling question asks what change of state occurs when forging cannon. The answer key lists words such as freezing, solidifying, and hardening. If students chose any of these words, the answer counts and they gain a shot. To accommodate for group dynamics and the differences in which different gendered groups finish the session activities, we developed supplementary session materials for students to complete if they finish the activities early (See Appendix N). The largest change to the session occurred in the miniature cannon design (See Appendix W). New springs fix all consistency problems and drastically increase the effectiveness of the mini cannon activity. The unclear reward system changed into a set of rules. Namely, students receive a shot for every correct answer in the scavenger hunt session. Students trade shots for variables, meaning that educators can monitor the number of shots students take and the number of variables changed per shot. The previous educator materials only outlined the session and did not delve into the science or specific discussion topics. The new educator materials explain exactly how to run the session (See Appendix A). These materials changed from a general run through to a well laid out and detailed lesson plan. The detailed lesson plan includes a step by step guide outlining the session format, key concepts to be discussed with the students, and clear descriptions of these science topics for a non-specialist with a full introduction to the session and its goals (see Appendix A).

Along with adapting our session to the student and teacher feedback, the Royal Armouries required differentiated versions of the session for varying academic abilities and inclement weather. To create a session for students of lower academic ability, all session materials changed format and wording while maintaining the same content. The differentiated signs contain simpler wording to better suit students who struggle with reading comprehension (See Appendix M). The differentiated workbook includes multiple choice

and closed procedure questions instead of open response (See Appendix F). Because Fort Nelson is subject to inclement weather and is in an exposed location, our session must work in poor weather conditions. To deal with this issue we created alternate locations for all signs that originally stand in Artillery Hall or on the Ramparts, and edited all session materials to accommodate for the location changes (See Appendix L, M). Finally, to suit the needs of students with higher academic abilities, we created an additional worksheet that further relates the scavenger hunt to the mini cannon activity and forces students to think critically about forces and projectile motion (See Appendix N). This worksheet provides extra materials for more advanced students or groups who finish other activities early. The session adaptations, although small, improve the session's quality and further incorporate the session into the Key Stage Three curriculum.

#### **4.7 Conclusions**

The session needed to reinforce topics from the Key Stage Three curriculum in interesting and innovative ways that actively educated students. Although the session focused on science, the session needed to relate to historically based exhibits throughout Fort Nelson. By relating science to exhibits throughout the museum and hands on activities, students grasped the concepts and reinforced subjects previously learned in the classroom. The session also looked into the scientific method which is a difficult and vague concept for students to grasp; as a result, it is a unit that Key Stage Three teachers tend to overlook due to the strict timeline incorporated into the curriculum.

The session split into three separate sections that relate to each other to provide a physical representation of higher science education. The first activity, the scavenger hunt, asked students many scientific questions and allowed them to explore Fort Nelson's collections in a controlled but free manner (See Appendix D). The second activity, the miniature cannon firing activity, gave students a chance to experience the effects of changing

certain cannon variables firsthand. This activity brought together many of the ideas from the first activity and related science to the real world. The final activity, the summary section, reviews key concepts from the previous activities. This part of the session brings together many scientific concepts that appear throughout the session and reinforces them through a familiar classroom learning style.

To collect accurate session feedback, we used informal interviews and questionnaires to assemble a broad range of opinions and perspectives about the session (See Appendixes P, Q). Along with informal interviews and questionnaires, other feedback collection methods included observations from team members aiding in the session, speaking with the educator following the session, and surveying both teachers and students at the end of the session. Discussion with the session educator at the conclusion of the session provided important suggestions for session and educator material improvement. The teacher surveys provided positive feedback and suggested areas that needed improvement (See Appendixes R2, T). The student surveys showed that the activities educated and challenged students without overwhelming or boring them (See Appendixes R1, S).

The adaptations to the session quickly fixed the main stumbling points found by the students during the test session. The differentiated session materials see to the needs of students with learning disabilities and focus on methods that help develop students' understanding. The educator materials changed to accommodate for a non-specialist educator, including discussion topics and a complete session outline (See Appendix A). We corrected the student workbooks and clarified the rewards system making the session far smoother and requiring less explanation from the educator. Through careful analysis, findings show that our session incorporates the Key Stage Three curriculum and the exhibits at Fort Nelson into a cohesive and educational session that provides an entertaining and educational experience for students ages eleven through fourteen.

## 5. Recommendations

Fort Nelson will soon be undertaking a large renovation to improve the overall learning and experience of its visitors. The proposed changes to the site include amending exhibit information displays, repositioning exhibits, and integrating technology into the classroom. Implementing these changes can greatly increase the capability of Fort Nelson to educate visitors, an integral part of the mission of the Royal Armouries.

The current exhibit signage provides historical background and a black and white sketch. While these displays may be sufficient for an adult visitor, they do not appeal to children. The large amount of words on most displays overwhelms most young visitors and the wording of the signs is well above their comprehension level. In order to appeal to both highly interested visitors and to less specialised guests, displays should include important and interesting facts about the exhibit that do not cover the displays with words. Having pictures on displays can increase the amount of attention paid to the display but can also take away from the actual piece on exhibition. Pictures on displays should be eye catching and highlight a key feature or component of the exhibit.

The current gallery layout confuses guests and detracts from the exhibit's cohesiveness. In the room titled "Age of Discovery" the gallery divides in two different directions with no marking or notification. The passage connecting the two halves of the Galleries is hidden behind a large sign. Finding this portion of the gallery proved difficult for some groups during the scavenger hunt activity of our site session. Ideally, the galleries would have a linear path so that visitors would not have to backtrack through to find this diversion. Moving the display and using signs to clearly identify the separate directions of the gallery could also solve this predicament.

Integrating technology into the classroom at Fort Nelson would most easily and effectively be achieved by the addition of an interactive whiteboard. SmartBoards are projector displays that also have touch control, creating an interactive environment. Having a large projector benefits the teaching process by being able to display key information such as instructions and key concepts. The addition of an interactive touch screen creates a hands-on environment in which educators can demonstrate the activity and allows students to learn from animated visuals. Our site session would benefit from a SmartBoard by having an interactive display of our cannon that could demonstrate projectile motion with the same variables built into it as the cannon from the session. This would show students the effect of each change made to the variables of the cannon and clearly display an image of the path of the projectile. This would also allow for the effects of other variables to be demonstrated including starting height, distance, type of projectile and even gravity. Although a SmartBoard provides a more interactive explanation of session topics, a computer and simple projector could display the same information.

## **7. Conclusion**

The site session created for the Royal Armouries at the Fort Nelson historical site is meant to inspire and educate Key Stage Three students in curriculum relevant science materials with a variety of learning techniques. The session employs three parts of very different learning techniques that work in succession to bring together many scientific concepts and apply them to real life.

The creation of the session required research into the historical background of artillery, interactive learning techniques, and the curricular restrictions on the session. Research revealed that learning is most effective in shorter sections that relate to each other and culminate in application of the material to something with which the students are already well versed. The Key Stage Three curriculum is not only strict on the material covered but also specifies the time allowed for each section. Research showed that the units relevant to artillery, and thusly the collections on display at Fort Nelson, are forces, energy, heating and cooling, and investigating scientific questions.

The prototype session split into three sections, which allowed students to explore Fort Nelson's vast collections, experience hands-on science applications, and it reinforced classroom learning. The first part of the session, the scavenger hunt, introduces many scientific concepts in simple terms and asks students questions based on specialised displays. The scavenger hunt urges students to think at a high level and applying reading comprehension to science principles. Once all students return, the educator reviews the correct answers and highlights key terms and concepts. Next, the miniature cannon activity uses knowledge based on the scavenger hunt and rewards students for answering questions correctly during the previous activity. Students attempt to shoot into the 'castle' within their limited amount of try's and with as few changes as possible to the variables built into the

cannons. Students record the results of each attempt and mark down the variable choices incorporated. The cannon activity brings out a competitive edge between student groups and encourages them to succeed. It also forces students to interact directly with many of the scientific principles already raised in the session. Once completed, the final portion of the session asks students what combination of variables they found to work best in the miniature cannon activity. The educator then leads a discussion of the forces involved in the previous activity covering many important and observable concepts. Finally, the educator leads a discussion of the many important science concepts that played major roles in the session. The educator applies them to topics students may grasp well already, to firmly root all the information from the session into the minds of the students.

All session materials are adaptable and designed to lend themselves well in many circumstances. The simpler version of the session features simplistic wordings and separated ideas to be easily understood by struggling students and students with learning disabilities (See Appendixes F, M). Both the simpler version for struggling children and the original version of the session are capable of functioning indoors in the case of inclement weather. To accommodate students of advanced academic ability and the student groups that may finish the scavenger hunt prior to their peers, the post scavenger hunt worksheet provides additional challenging questions and urges students to think critically about the miniature cannon activity before it begins (See Appendix N). The session educator materials contain a full walkthrough of the session and highlight key concepts to be covered; they are designed to be appropriate for a non-specialist presenter to deliver to a student group as well (See Appendix A). This ensures that the presenter has a clearly defined list of the important concepts raised in the session and that the students will receive the full educational experience intended to come from the session.

Findings from research applied to the creation of the session shaped it into its final form by combining many of the key principles uncovered and focusing on keeping the session in a constant forward progression. The observations and surveys from the test session revealed the early stumbling points and highlighted areas of difficulty within the session; these corrections were readily applied and worked upon to make the finalised session an excellent educational experience. All findings were continually integrated into the session as they were uncovered in the continual development of the finalised session.

The proposed future renovations to Fort Nelson have the potential to increase the educational experience of its visitors. The session may also greatly benefit from the renovations as some of the renovations are focused on improving the classroom where the majority of the session takes place.

The educational site session created for the Royal Armouries at the Fort Nelson historical site is a great educational tool to instruct Key Stage Three students in curriculum appropriate science material. Employing an array of learning techniques and having them build upon each other in a cohesive manner only serves to strengthen the educational experience for the participating students. Though the session takes place in under two hours, the knowledge absorbed from the activity will stay with the students long after they have left.



## Appendices

### Appendix A – Staff Education Materials

The staff education materials are given to the educator hosting the session. The materials give an outline of the session and give background for the areas of focus during the session.

## Artillery Science Presenter Materials

Goals:

- Apply science to artillery
- Draw scientific conclusions from experiments
- Develop scientific enquiry, teamwork and communication skills through experimentation

Focus:

- Forces
- Heating and cooling
- Energy and fuel

Timing:

\* If not occurring devote more time to analysis

Introduction	15 minutes
Scavenger Hunt	30 minutes
Gather back together	10 minutes
Mini cannon activity	30 minutes
*Noon cannon fire viewing (if possible)	(15 minutes)
Analysis	15 minutes
Total	100 minutes (115 minutes)

Notes:

- **Session requires one adult escort per student group to accompany them**
- **Teacher should select either the standard version of the session or the version for struggling students prior to their arrival**

### Session Setup

- Print one handout per student group as appropriate for weather and abilities
- Print one post scavenger hunt activity sheet per student group
- Print one answer key per teacher and one for the session educator

- Place appropriate signs on the specified exhibits in sight of students (follow sign placement guide based on abilities and weather)
- Place one handout on each group table with a clipboard and pencil
- Place the castle crate near a corner of the room
- Mark out firing lines on an arc 2 meters from the centre of the castle crate for each group

## **Introduction to the session and RA (15 minutes)**

Today we are hoping to turn you into Fort Nelson Artillery Scientists. You are going to see how science is important to us here at Fort Nelson and how it relates to our collection. You will have to work together, discover and apply ideas about artillery and use all that you have learned to succeed at the final experiment. We will be looking at **forces, heating and cooling, and energy**.

In your groups you will have 30 minutes to look around Fort Nelson for your science clues. Each clue has a question in your booklet for your group to answer. These questions ask you about different aspects of science relating to artillery and Fort Nelson. Answering all these questions will strengthen your scientific knowledge and help you train to siege a castle with your group's own mini cannon.

## **Scavenger hunt (30 minutes)**

- Materials:
  - For educator: Sample display, answer key
  - For each group: handout, writing utensil, clipboard
- Explain 'reward' system
  - Team will receive 1 projectile per correct answer
  - One shot can be traded in order to change one variable between shots
- Show example display so groups know what to look for
- Divide class into groups of 4 or more students and one teacher
- Student roles:
  - Recorder- to take down the group answers to the questions
  - Navigator- to make sure the group knows where they are headed
  - Time Keeper- to make sure the group will return on time
  - Scout(s)- to look for the clues
- After student groups leave to complete the activity:
  - Place one post scavenger hunt activity sheet on each group table
  - Place the appropriate number of mini cannons just behind the lines marked out

## **Mini Cannon Siege (30 minutes)**

- Materials:
  - For educator: Sample display, masking tape shots, castle crate

-For each group: 2 safety goggles, Mini Cannon, plunger, materials from Scavenger Hunt

- Student groups that return early should be instructed to check their answers and look at the post scavenger hunt activity sheet to think about the next activity
  - Students should be told that the activity sheet will not be marked and is only meant to help set their minds properly for the following activity
- Once all student groups return call the students to order and complete the following:
  - Students' answers from the scavenger hunt are reviewed by another group and looked over by teacher with answer key
  - Session instructor will go over the questions asking students for what they think is the right answer and if necessary reading the correct response from the answer key
    - Answers should be marked correctly for the inclusion of keywords listed in the answer key or any reasonable answer for free response questions
    - The marking group should add up the number of correct answers and write it on the page before returning it to the group whom answered the questions
- Groups are given projectiles equal to their number of correct answers. Collect one shot to change a variable between shots.
- Explain/demonstrate use of mini cannon and related science concepts
  - Forces
    - **Gravity**-pulling down on projectile, use angle to fight gravity
    - **Air resistance**- friction caused by rubbing against air molecules
    - **Push from Spring**
  - **Stored energy (Potential energy)** - Energy stored for future movement
    - In spring-representation of **fuel**. Where does it come from?
    - When projectile is at the top of its path
  - **Kinetic energy** -Energy due to an object's motion
    - When projectile is flying
- Students aim to shoot their cannon **into** the castle in their given amount of shots
- Only **change one variable per shot** so the students can see the effect of every change
- Students may move the cannons **behind** the firing lines but **not in front**

## Noon cannon fire viewing if possible (15 minutes)

- Take students to view the noon firing of the cannon and gather them back to the classroom for the final section

## Analysis (15 minutes)

- Review science topics from previous activities
  - Analyse the different forces
  - Discuss the best shot combination
    - Groups may take one more final shot with their combination (based on time)
- Discuss how science is all around us
  - Gravity- holds us to Earth
  - Energy- in food we eat and we use it when we do things
  - Air resistance- slows down everything that moves through the air
  - Mass- we all have mass and so does everything else

- Reaction forces- gravity pulls us down but we push back with an equal and opposite force, otherwise we'd sink through the floor

## Appendix B - Sign placement guide

<b>Sign</b>	<b>Museum Location</b>
Cannon Casting	Forge
Amazing Ammo	India Iron Gun-Blenheim to Waterloo Room in the Gallery
Super Shooter	Iraqi Gun-Artillery Hall
Mass Matters	Dardanelles Gun-Artillery Hall
Why Here?	Rampart with cannon
Man or Machine?	Bronze Dragon gun-Art Room in the Gallery
Newton Knew It!	4 <sup>th</sup> gallery
In A Spin	Rifled barrels in the Gallery
The Big Bang	Gunpowder in hallway in Gallery on the way to the Forge
Poor Weather	
<b>Sign</b>	<b>Museum Location</b>
Cannon Casting	Forge
Amazing Ammo	India Iron Gun-Blenheim to Waterloo Room in the Gallery
Super Shooter	
Mass Matters	First gallery
Why Here?	Cannon pointed out window in gallery
Man or Machine?	Bronze Dragon gun-Art Room in the Gallery
Newton Knew It!	4 <sup>th</sup> gallery
In A Spin	Rifled barrels in the Gallery
The Big Bang	Gunpowder in hallway in Gallery on the way to the Forge

Given to the session educator to place the signs in the correct places for the session.

## Appendix C - Risk Assessment

Standard risk assessment form for a Royal Armouries session. Completed by the project team and reviewed by Royal Armouries Staff. The risk assessment is available to teachers and anybody interested in the risk of the session.

Royal Armouries Museum  
FORM RA001

### GENERAL AREA RISK ASSESSMENT

Sheet No – 1 Assessor – WPI Location of risk assessment – Fort Nelson RA Activity being assessed – Artillery Science site session Date of activity – Date assessment completed – 26 May 2010	WHO will be affected? i.e. staff/public		HOW would the hazard cause injury? e.g. wire would cause - trip/fall	ACCIDENT – What would the injury be? e.g. cut/bruise	SEVERITY 1 Minor Injury 2 Major Injury 3 Single Death 4 Multiple Death	LIKELIHOOD OF HAZARD OCCURRING	SEVERITY TIMES LIKELIHOOD GIVES	Further assessment needed i.e. COSHH/ DSE/ Manual Handling	Control Measures in place	REVISED RISK RATING TAKING INTO ACCOUNT CONTROLS
	1 Very unlikely 2 Unlikely 3 Likely 4 Very likely	1 2 3 4	1 2 3 4	1 2 3 4	RISK SCORE	YES/NO	Severity (this will be the same) Likelihood should be reduced S X L = NEW SCORE			
HAZARD – What is it that's causing the problem? e.g. Trailing Wire	Teachers Students	Launch object	Bruise Eye injury	2	2	4	No	Goggles, failure to abide by rule results in activity being stopped	2	
Spring	Teachers Students	Poke people Shoot it Splinters	Bruise Eye injury	2	2	4	No	Acceptable behavior explained, failure to do this results in activity being stopped	2	
Dowel	Teachers Students	Drop it	Pain	1	1	1	No	Children are reminded that object must be handled carefully	1	
Weight	Teachers Students	Scrape Fall on it	Cut	2	1	2	No	File corners, remind children to be careful	1	
Sharp corners	Teachers Students	Pinch Fingers	Pain	1	1	1	No	Children are reminded to be careful with equipment and warned against moving parts	1	
Hinge	Teachers Students	Trip	Bruise Scrape	2	2	4	No	Stay out of tunnels, don't run, be careful, failure to follow rules subtracts shots and variables	2	
Tripping	Students	Burns Hearing loss	Bums Hearing loss	2	1	2	No	Listen to instructions about cannon firing	2	
Cannon firing	Students Teachers									

I as Head of the Department sign to say I have reviewed the hazards & risks and agree with the controls in place. .... Date .....

Signed by Assessor ..... Signed by H&S Advisor ..... Date of review .....

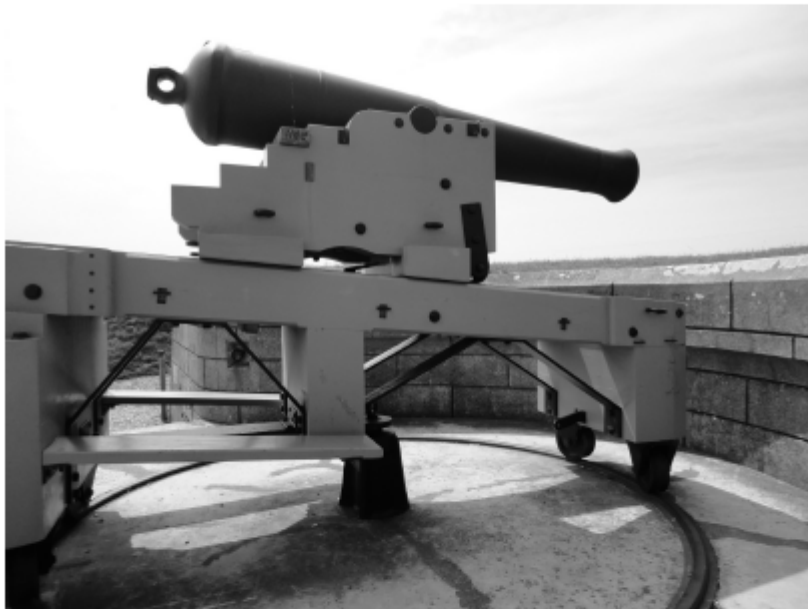
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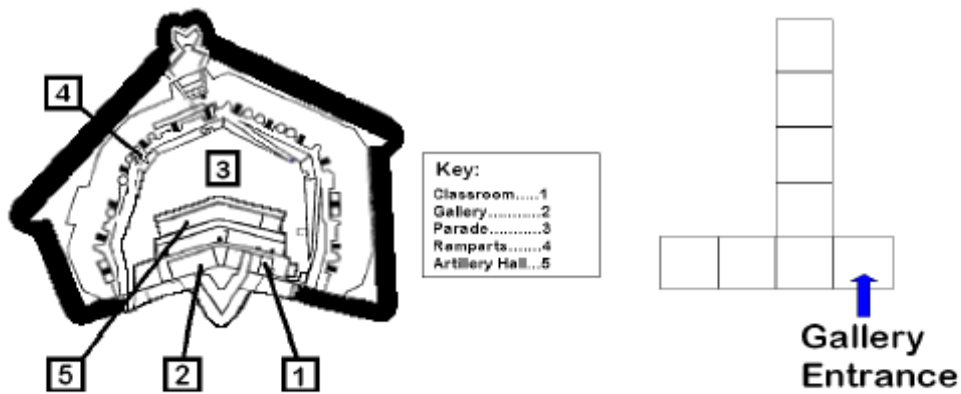
## **Appendix D – Standard Workbook**

Standard workbook given out for students who do not have any academic issues and the weather is nice enough for the students to go outside.

# **Artillery Science**

**You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!**





Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

**Gallery:**

1. **Cannon Casting:** What change of state occurs when a cannon mould is filled and cooled?

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2. **The Big Bang:** What actually forces the projectile out of the cannon barrel?

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3. **Amazing Ammo:** Why does this gun work better for multiple smaller-sized targets?

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4. **Newton Knew It!:** Why are cannons angled up?

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5. **Man or Machine:** Why is it sometimes better to have smaller projectiles?

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6. **In A Spin:** Why is there less air resistance if the projectile is spinning?

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**Artillery Hall:**

7. **Mass Matters:** What is the mass of the Dardanelles gun's projectile on the moon?

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8. **Super Shooter:** What advantage do artillery officers have with a longer range gun?

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**Ramparts:**

9. **Why Here:** Why is it better to have a fort high up on top of a hill?

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### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1

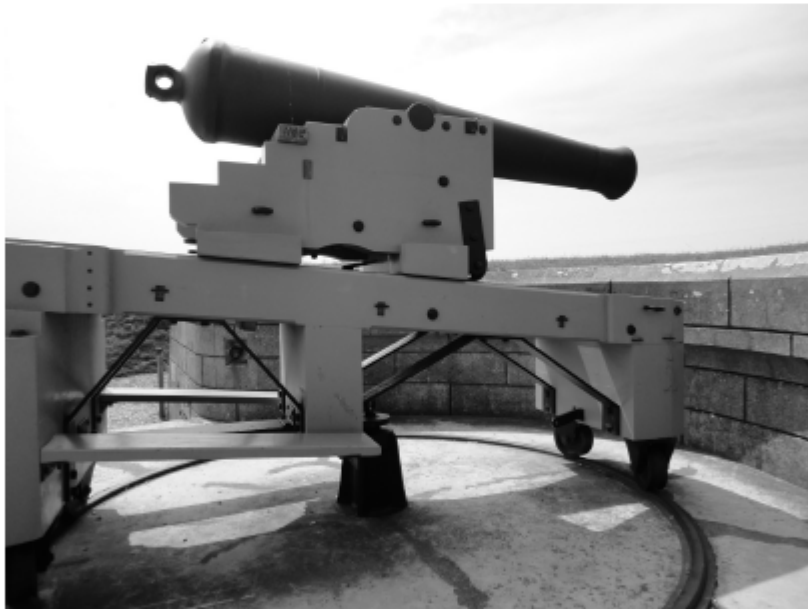


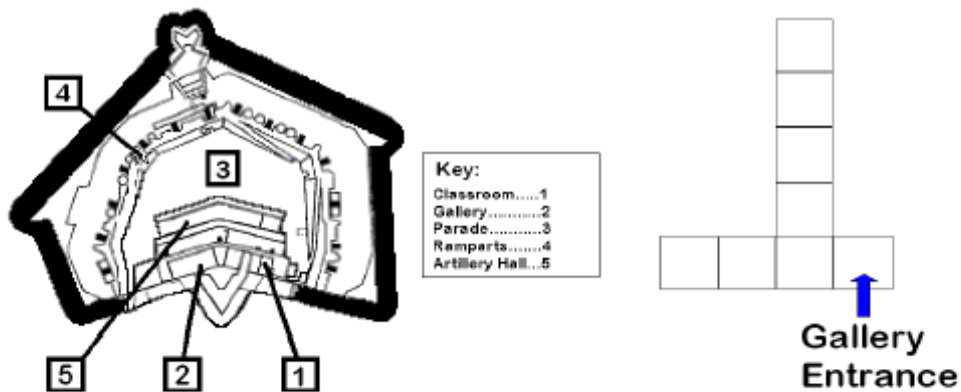
## Appendix E – Standard Workbook Answer Key

The answer key for the standard workbook.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!





Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

### Gallery:

1. **Cannon Casting:** What change of state occurs when a cannon mould is filled and cooled?

Solidifies, freezes, hardens, changes from liquid to solid

2. **The Big Bang:** What actually forces the projectile out of the cannon barrel?

Carbon Dioxide

3. **Amazing Ammo:** Why does this gun work better for multiple smaller-sized targets?

More shots at once, shoot over a larger area

4. **Newton Knew It!:** Why are cannons angled up?

To fight against gravity, shoot further

5. **Man or Machine:** Why is it sometimes better to have smaller projectiles?

More moveable

6. **In A Spin:** Why is there less air resistance if the projectile is spinning?

Keeps ammo in straight path. Stops projectile from tumbling through the air

### **Artillery Hall:**

7. **Mass Matters:** What is the mass of the Dardanelles gun's projectile on the moon?

304 kg

8. **Super Shooter:** What advantage do artillery officers have with a longer range gun?

Officer is at a safe distance while still being in range of target

### **Ramparts:**

9. **Why Here:** Why is it better to have a fort high up on top of a hill?

Increased range and sight, better defensive positioning

### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1



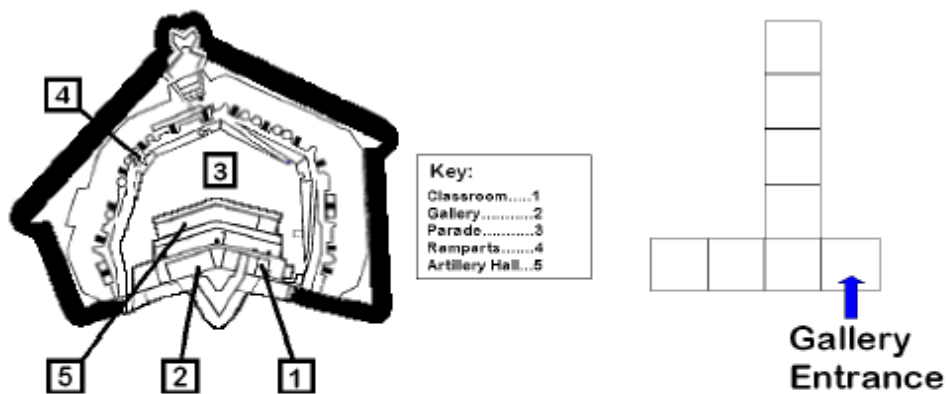
## Appendix F – Differentiated Workbook

The workbook given to students at a lower academic level or with disabilities.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!





Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

### Gallery:

- Cannon Casting:** When making a cannon, the melted metal cools from a \_\_\_\_\_ to a \_\_\_\_\_.
- The Big Bang:** What actually makes the cannonball fly?
  - Carbon Dioxide
  - Gravity
  - Heat
- Amazing Ammo:** This gun works better for \_\_\_\_\_ targets because it fires many shots.
- Newton Knew It!** Why are cannons angled up?
  - To keep the cannonball in
  - To fight against gravity
  - To cut down friction



5. **Man or Machine:** Why is it sometimes better to have smaller cannonballs?

- A) Causes more damage
- B) Shoots further
- C) Easier to move around

6. **In A Spin: Rifling causes the ammo to \_\_\_\_\_** which stops it from tumbling through the air.

**Artillery Hall:**

7. **Mass Matters:** The mass of the Dardanelles gun's shot on the moon is \_\_\_\_\_ kg

8. **Super Shooter:** Why is it better to be able to shoot further?

- A) Safer
- B) To help you hit the target
- C) Can shoot multiple targets at once

**Ramparts:**

9. **Why Here:** Why is it better to have a fort high up on top of a hill?

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### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1

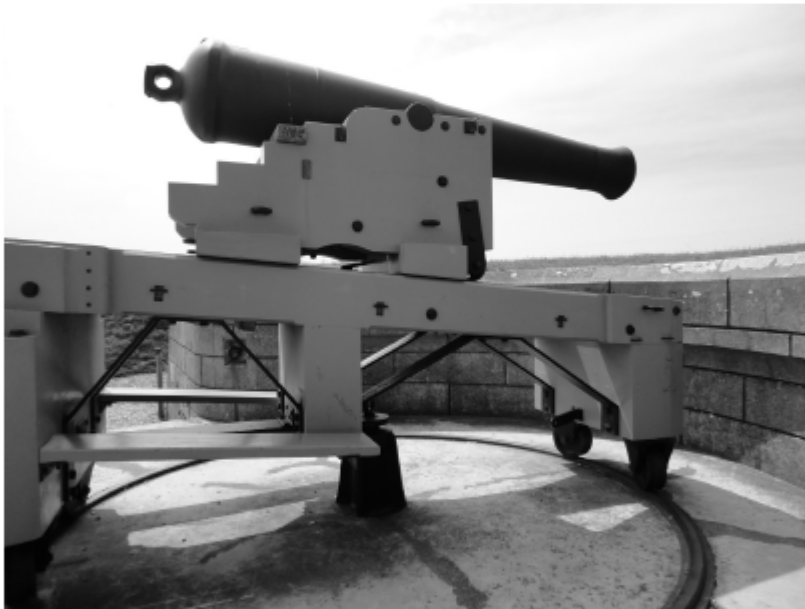


## Appendix G - Differentiated Workbook Answer Key

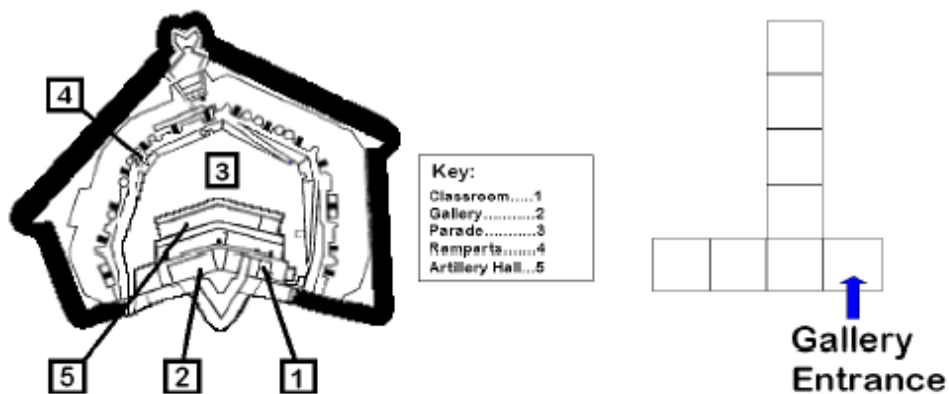
Answer key for the differentiated workbook.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!







Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

### Gallery:

- Cannon Casting:** When making a cannon, the melted metal cools from a liquid to a solid.
- The Big Bang:** What actually makes the cannonball fly?
  - Carbon Dioxide
  - Gravity
  - Heat
- Amazing Ammo:** This gun works better for many targets because it fires many shots.
- Newton Knew It!:** Why are cannons angled up?
  - To keep the cannonball in
  - To fight against gravity
  - To cut down friction

5. **Man or Machine:** Why is it sometimes better to have smaller cannonballs?

- A) Causes more damage
- B) Shoots further
- C) Easier to move around

6. **In A Spin:** Rifling causes the ammo to spin which stops it from tumbling through the air.

### Artillery Hall:

7. **Mass Matters:** The mass of the Dardanelles gun's shot on the moon is 304 kg

8. **Super Shooter:** Why is it better to be able to shoot further?

- A) Safer
- B) To help you hit the target
- C) Can shoot multiple targets at once

### Ramparts:

9. **Why Here:** Why is it better to have a fort high up on top of a hill?

Easier to defend, shoot further, see further

### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1



## Appendix H – Workbook for Inclement Weather

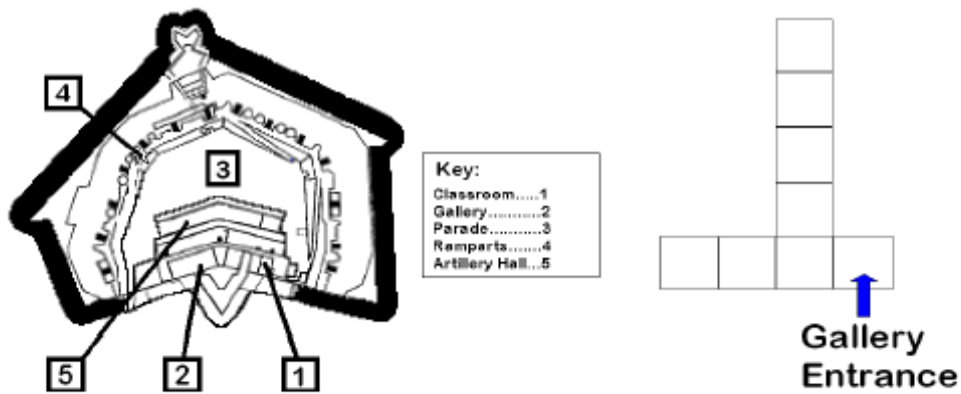
Workbook given out and used if the weather does not let the students go outside at the Fort. Questions keep students inside at all times.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!







Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

**Gallery:**

1. **Cannon Casting:** What change of state occurs when a cannon mould is filled and cooled?

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2. **The Big Bang:** What actually forces the projectile out of the cannon barrel?

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3. **Amazing Ammo:** Why does this gun work better for multiple smaller-sized targets?

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4. **Newton Knew It!:** Why are cannons angled up?

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5. **Man or Machine:** Why is it sometimes better to have smaller projectiles?

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6. **In A Spin:** Why is there less air resistance if the projectile is spinning?

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7. **Why Here:** Why is it better to have a fort high up on top of a hill?

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**Artillery Hall:**

8. **Mass Matters:** What is the mass of the Dardanelles gun's projectile on the moon?

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9. **Super Shooter:** What advantage do artillery officers have with a longer range gun?

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### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1

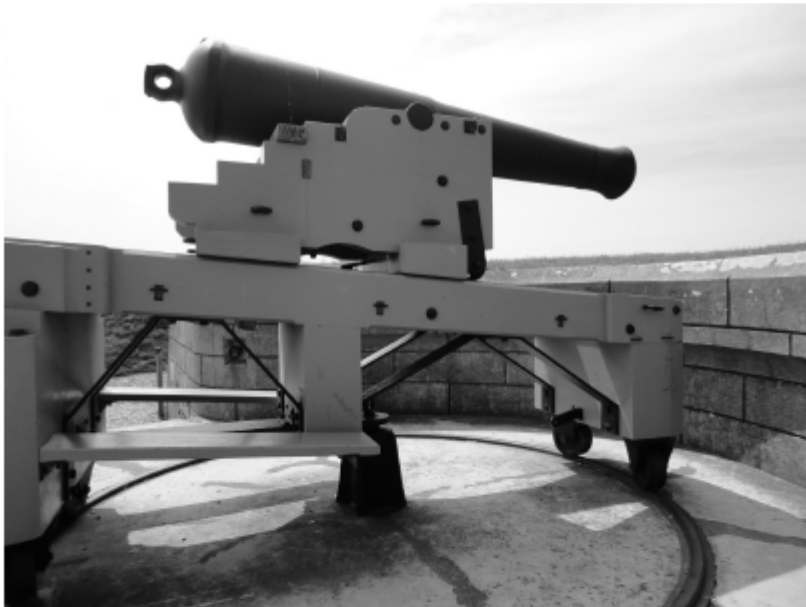


## Appendix I – Inclement Weather Workbook Answer Key

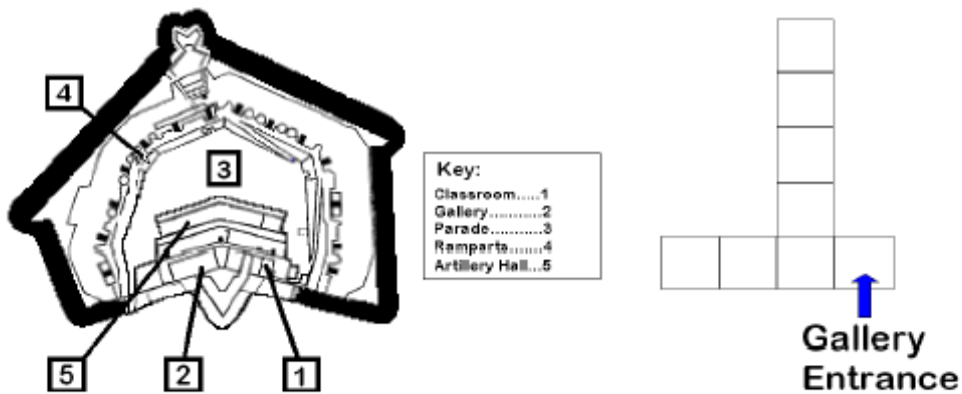
Answer Key for the inclement weather workbook.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!







Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

### Gallery:

1. **Cannon Casting:** What change of state occurs when a cannon mould is filled and cooled?

Solidifies, freezes, hardens, changes from liquid to solid

2. **The Big Bang:** What actually forces the projectile out of the cannon barrel?

Carbon Dioxide

3. **Amazing Ammo:** Why does this gun work better for multiple smaller-sized targets?

More shots at once, shoot over a larger area

4. **Newton Knew It!:** Why are cannons angled up?

To fight against gravity, shoot further

5. **Man or Machine:** Why is it sometimes better to have smaller projectiles?

More moveable

6. **In A Spin:** Why is there less air resistance if the projectile is spinning?

Keeps ammo in straight path. Stops projectile from tumbling through the air

7. **Why Here:** Why is it better to have a fort high up on top of a hill?

Increased range and sight, better defensive positioning

### **Artillery Hall:**

8. **Mass Matters:** What is the mass of the Dardanelles gun's projectile on the moon?

304 kg

9. **Super Shooter:** What advantage do artillery officers have with a longer range gun?

Officer is at a safe distance while still being in range of target

### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1





## Appendix J – Differentiated and Inclement Weather Workbook

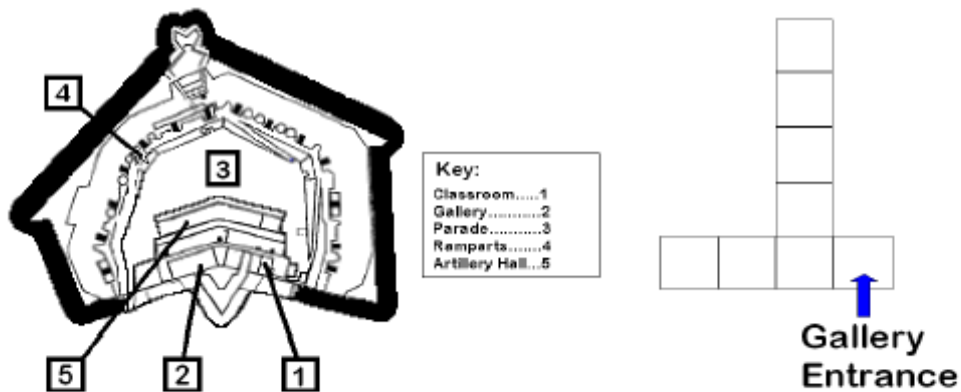
Workbook used for the students of lower academic level while the weather does not permit the students to go outside.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!







Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

### Gallery:

- Cannon Casting:** When making a cannon, the melted metal cools from a \_\_\_\_\_ to a \_\_\_\_\_.
- The Big Bang:** What actually makes the cannonball fly?
  - Carbon Dioxide
  - Gravity
  - Heat
- Amazing Ammo:** This gun work better for \_\_\_\_\_ targets because it fires many shots.
- Newton Knew It!:** Why are cannons angled up?
  - To keep the cannonball in
  - To fight against gravity
  - To cut down friction

5. **Man or Machine:** Why is it sometimes better to have smaller cannonballs?

- A) Causes more damage
- B) Shoots further
- C) Easier to move around

6. **In A Spin: Rifling cause the ammo to \_\_\_\_\_** which stops it from tumbling through the air.

7. **Why Here:** Why is it better to have a fort high up on top of a hill?

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#### Artillery Hall:

8. **Mass Matters:** The mass of the Dardanelles gun's shot on the moon is \_\_\_\_\_ kg

9. **Super Shooter:** Why is it better to be able to shoot further?

- A) Safer
- B) To help you hit the target
- C) Can shoot multiple targets at once

### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1

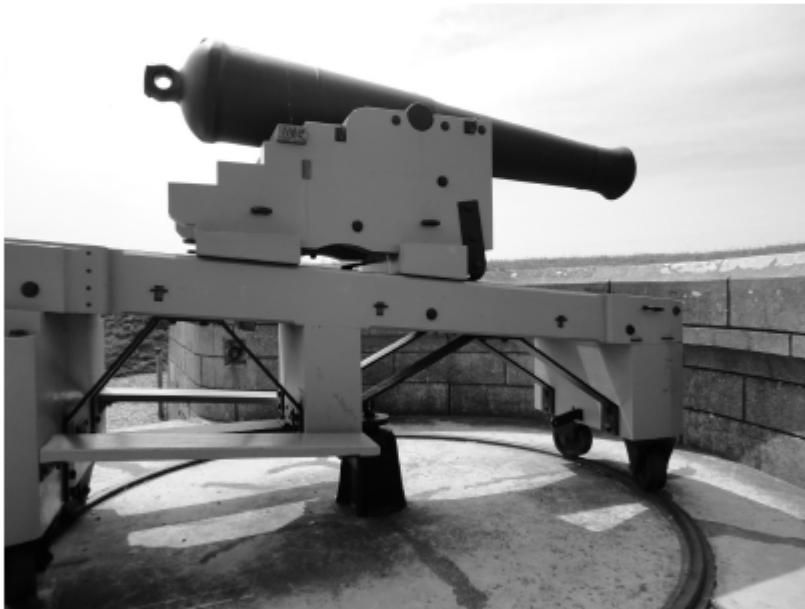


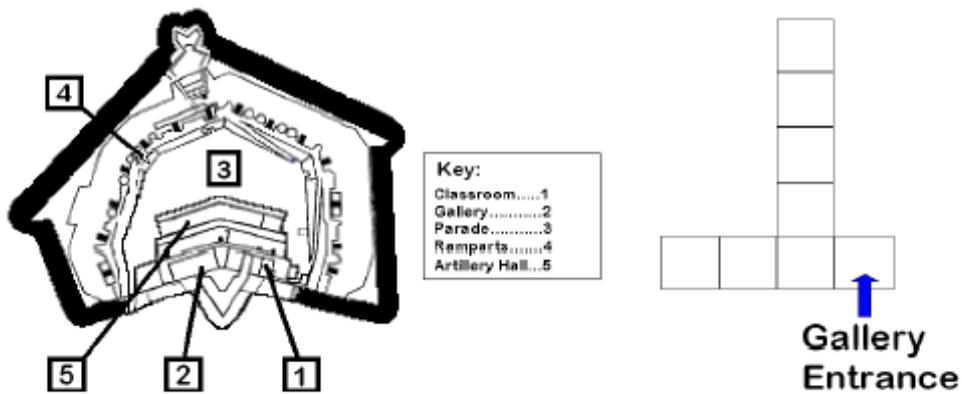
## Appendix K – Differentiated, Inclement Weather Workbook Answer Key

Answer key for the differentiated inclement weather workbook.

# Artillery Science

You are training to be an artillery officer. Explore the museum to discover the science behind artillery and help improve your skills. Then apply the information you have learnt by using your own cannon to siege an enemy castle!





Find these exhibits and answer the questions:

Remember, the more questions you answer the more shots you earn!

### Gallery:

- 1. Cannon Casting:** When making a cannon, the melted metal cools from a liquid to a solid.
- 2. The Big Bang:** What actually makes the cannonball fly?
  - A) Carbon Dioxide
  - B) Gravity
  - C) Heat
- 3. Amazing Ammo:** This gun works better for many targets because it fires many shots.
- 4. Newton Knew It!:** Why are cannons angled up?
  - A) To keep the cannonball in
  - B) To fight against gravity
  - C) To cut down friction

5. **Man or Machine:** Why is it sometimes better to have smaller cannonballs?

- A) Causes more damage
- B) Shoots further
- C) Easier to move around

6. **In A Spin:** Rifling causes the ammo to spin which stops it from tumbling through the air.

#### Artillery Hall:

7. **Mass Matters:** The mass of the Dardanelles gun's shot on the moon is 304 kg

8. **Super Shooter:** Why is it better to be able to shoot further?

- A) Safer
- B) To help you hit the target
- C) Can shoot multiple targets at once

#### Ramparts:

9. **Why Here:** Why is it better to have a fort high up on top of a hill?

Easier to defend, shoot further, see further



### Mini Cannon Results:

Shot #	Power level	Angle	What happened?	What next?
1				Take another shot Change angle -1 Change power -1
2				Take another shot Change angle -1 Change power -1
3				Take another shot Change angle -1 Change power -1
4				Take another shot Change angle -1 Change power -1
5				Take another shot Change angle -1 Change power -1
6				Take another shot Change angle -1 Change power -1
7				Take another shot Change angle -1 Change power -1

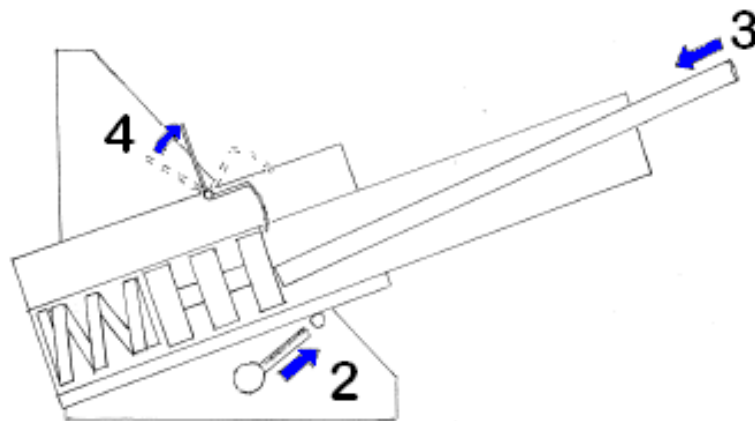


## Appendix L – Scavenger Hunt Signs

Set of scavenger hunt signs used for standard students independent of weather. First sign (Appendix L1) is used as a model to show the students what the signs look like throughout the museum as well as give an example of how to use the cannons to the students.

### Appendix L1 – Mini Cannon Directions Sign

# Mini Cannons



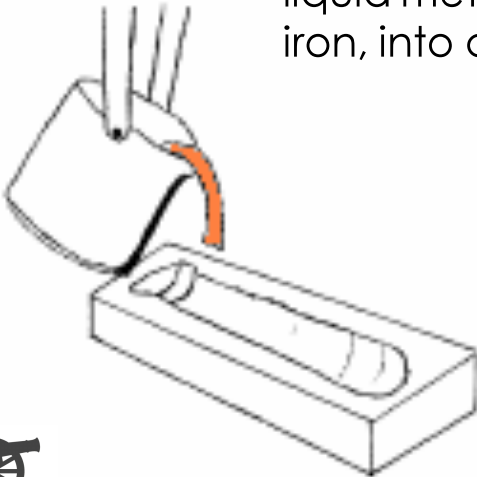
- Step 1: Put on your safety goggles
- Step 2: Choose angle and use bolt to secure cannon
- Step 3: Use plunger to choose power setting
- Step 4: Lock the trigger
- Step 5: Load the cannon
- Step 6: Launch cannonball!



**ROYAL ARMOURIES**

# Cannon Casting

A cannon is made by pouring hot liquid metal, like iron, into a mould.



As the metal cools it hardens into a solid cannon.

You can see many examples throughout the museum!



**ROYAL ARMOURIES**

# Amazing Ammo



This gun looks different,  
doesn't it?

That's because instead of  
shooting a round cannonball  
it shoots many smaller  
projectiles, which is better for  
multiple targets.



**ROYAL ARMOURIES**

# Super Shooter



34 km

Fort Nelson has a gun that can shoot up to 39.6 km, which means it can shoot across the English Channel!

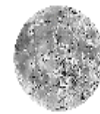
This unique gun keeps the artillery officers at a safe distance while being in range of a target.



# Mass Matters



Everything has a constant mass. Weight however can vary with the location of an object. On the Moon where gravity is a lot weaker an object would weigh a lot less.



$$\text{Weight} = \text{Mass} \times \text{Gravity}$$



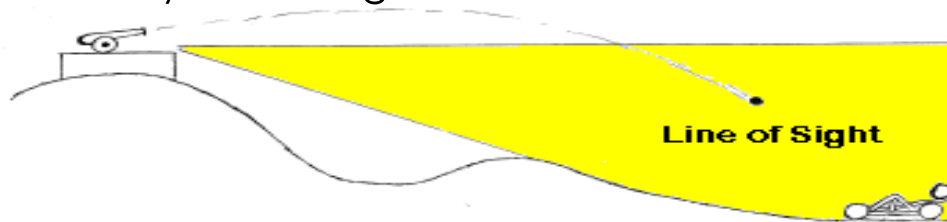
The mass of the Dardanelles gun's projectile on Earth is 304 kg

**ROYAL ARMOURIES**

# Why Here?



Fort Nelson is on top of a large hill. This means it has a great defensive position. The Fort's cannons have an extended range and soldiers would have a better view of any attacking forces.

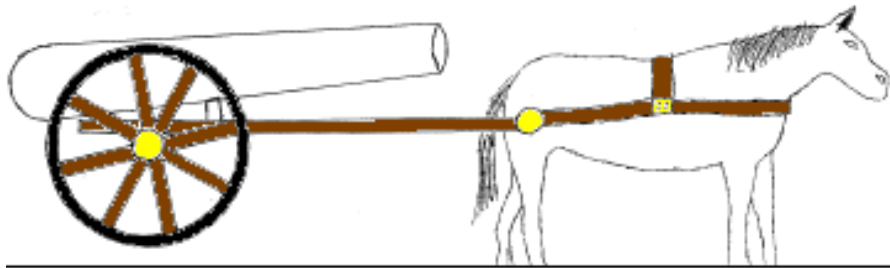




## Man or Machine?

Cannons fire many different size projectiles depending on their barrel size.

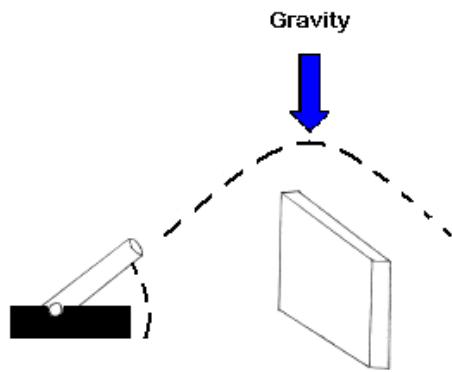
It is sometimes better to have smaller projectiles fired from a smaller cannon, so it is easier to move around!



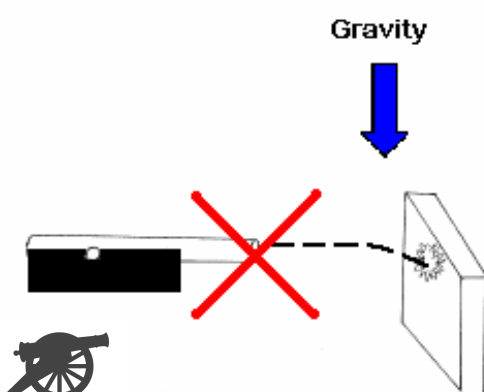
**ROYAL ARMOURIES**



# Newton Knew It!



Gravity is the force that brings all objects back to Earth.

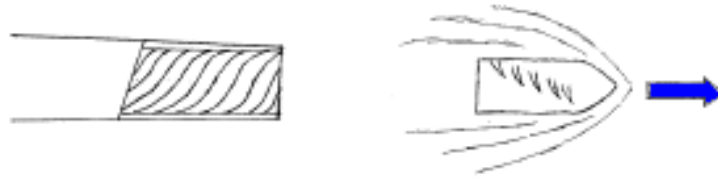


When we fire cannons over long distances they have to fight against this force and so we fire them at an upward angle.

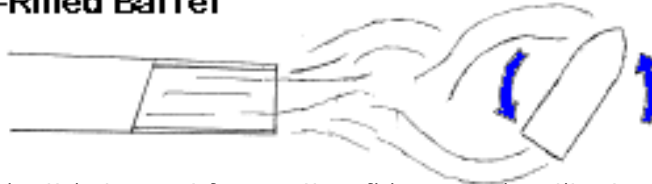


## In A Spin

Rifled Barrel



Non-Rifled Barrel



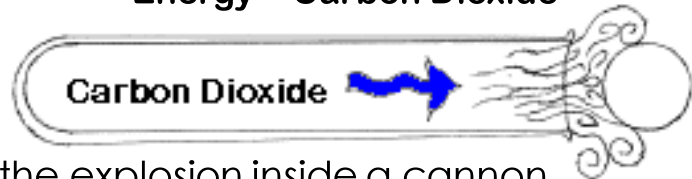
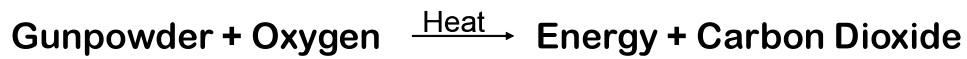
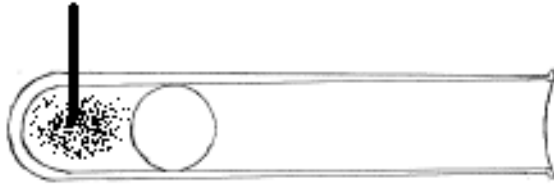
The grooves in this barrel force the firing projectile to spin as it comes out of the barrel.

This keeps the projectile moving in a straight path rather than letting it tumble through the air, and therefore minimises air resistance.



# The Big Bang

Gunpowder



Gunpowder is the fuel for the explosion inside a cannon.

This combustion reaction creates a lot of carbon dioxide gas, which produces enough force to push the projectile soaring through the air.



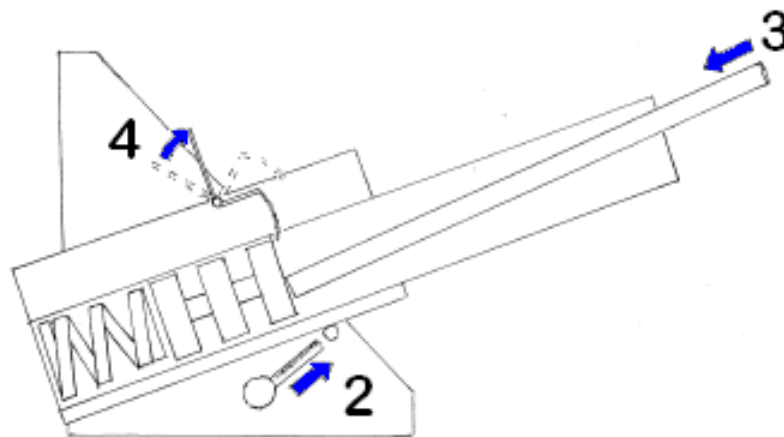
**ROYAL ARMOURIES**

## Appendix M – Signs for Differentiated Session

Set of scavenger hunt signs used for students of lower academic weather independent of the weather. The first sign (Appendix M1) is used as a model to show the students what the signs look like throughout the museum as well as give an example of how to use the cannons to the students.

### Appendix M1 – Differentiated Mini Cannon Directions Sign

# Mini Cannons



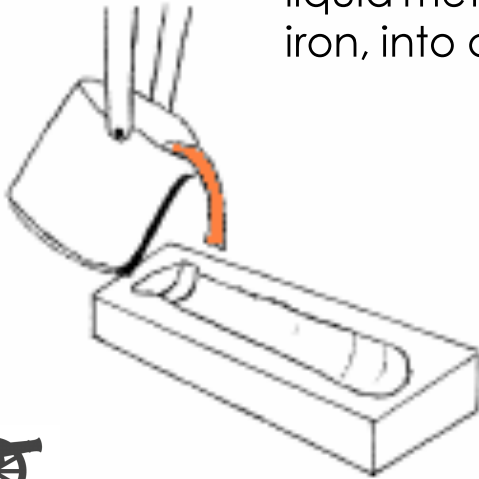
- Step 1: Put on your safety goggles
- Step 2: Pick angle and use bolt to hold cannon
- Step 3: Use plunger to choose power setting
- Step 4: Lock the trigger
- Step 5: Load the cannon
- Step 6: Launch cannonball!



**ROYAL ARMOURIES**

# Cannon Casting

A cannon is made by pouring hot liquid metal, like iron, into a mould.



As the metal cools it hardens into a solid cannon.

You can see many examples all over the museum!



**ROYAL ARMOURIES**

# Amazing Ammo



This gun looks different,  
doesn't it?

That's because instead of  
shooting a large cannonball  
it fires many smaller shots,  
which is better for lots of  
targets.



# Super Shooter



34 km

Fort Nelson has a gun that can shoot up to 39.6 km, which means it can shoot across the English Channel!

This gun keeps the artillery officers at a safe distance while still being able to reach the target.



**ROYAL ARMOURIES**

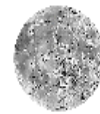
# Mass Matters



Everything has a mass that stays the same.

But... weight can change with location.

On the Moon where gravity is weaker an object would weigh less.



$$\text{Weight} = \text{Mass} \times \text{Gravity}$$

The mass of the Dardanelles gun's shot on Earth is 304 kg

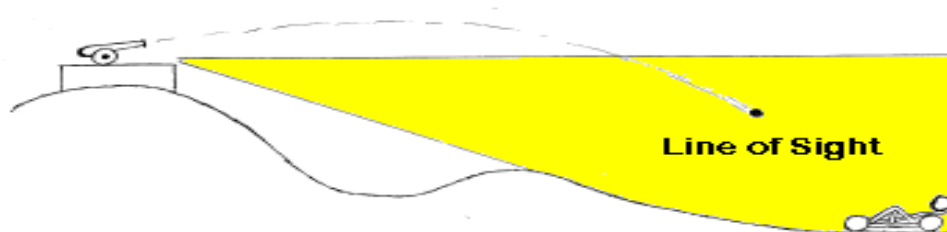




# Why Here?



Fort Nelson is on top of a large hill. This means soldiers would have a better view of any enemies. The hill also helps the cannons fire further.

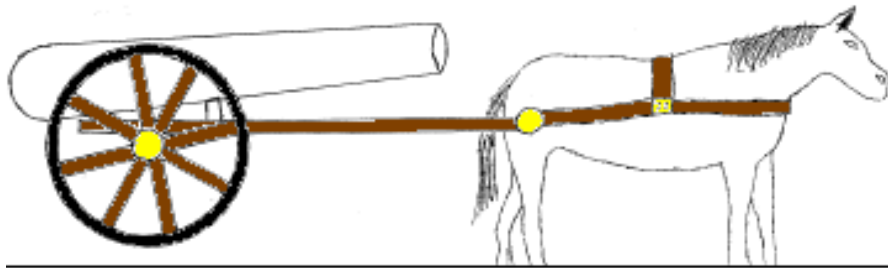




## Man or Machine?

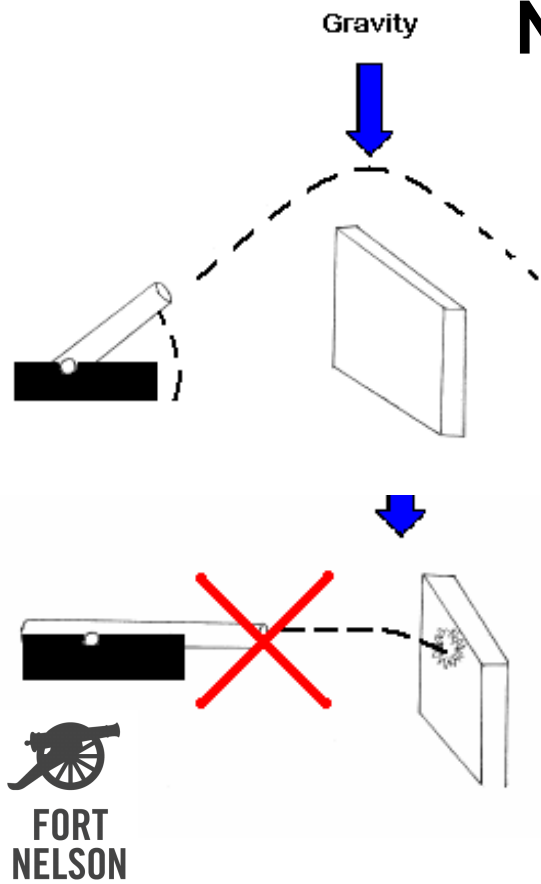
Cannons fire many different size cannonballs depending on their size.

It is sometimes better to have smaller ammo fired from a smaller cannon, so the cannon is easier to move around!



**ROYAL ARMOURIES**

# Newton Knew It!



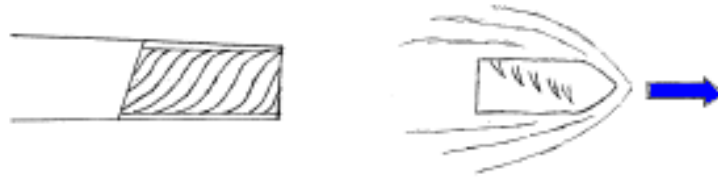
Gravity is the force that brings everything back to Earth.

When we fire cannons they have to fight against gravity so we fire them upwards.

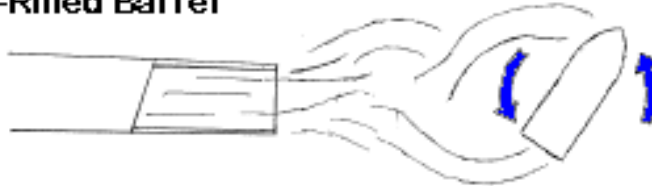
**ROYAL ARMOURIES**

## In A Spin

Rifled Barrel



Non-Rifled Barrel



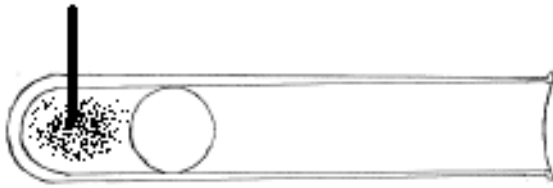
The grooves in this barrel force the shot to spin.

This makes it fly straight and cuts down on air resistance, rather than letting it tumble through the air.

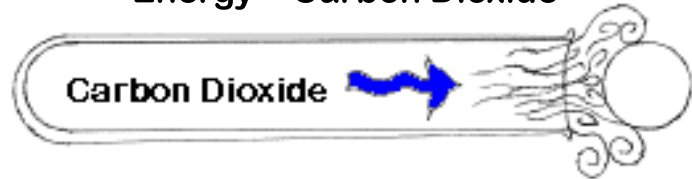


# The Big Bang

Gunpowder



Gunpowder + Oxygen  $\xrightarrow{\text{Heat}}$  Energy + Carbon Dioxide



Gunpowder is the fuel for the explosion inside a cannon.

This explosion creates the gas **carbon dioxide**, which pushes the shot through the air.

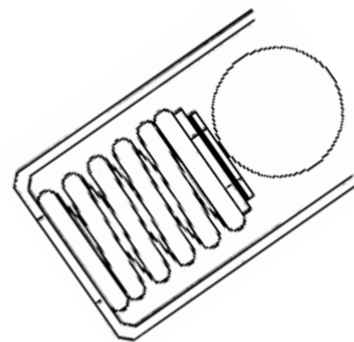


ROYAL ARMOURIES

Appendix N – Post Scavenger Hunt Advanced Student Worksheet

# Post Scavenger Hunt Activity Sheet

Where is energy being stored in this picture?



Where do you see reaction forces in this picture?

What forces act on the projectile while it is in the air? Which way are they going?

Here is what the path of the projectile should look like at a 30 degree angle and a medium power setting:



Draw what path you think the projectile will follow when it is shot from a higher starting position (hint: think about the Why Here? sign).



---

Draw what path you think the projectile will follow when it is shot at a bigger angle setting (hint: think about the Newton Knew it sign).



---

Draw what path you think the projectile will follow when it is shot it with a higher power setting.



---

What do you think would happen if the following different kinds of ammo were shot from our cannon (hint: think about the Amazing Ammo sign)?

A heavy marble-

A cotton ball-

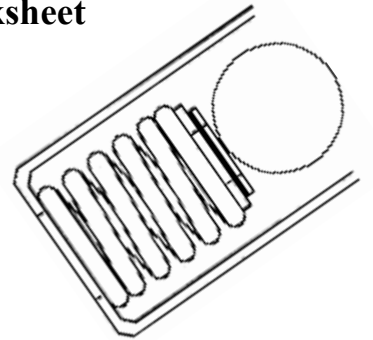
5 smaller masking tape balls all at once-

Why would we not use these to shoot from our cannon?



Appendix O - Post Scavenger Hunt Advanced Student Worksheet  
Answer Key

# Post Scavenger Hunt Activity Sheet



Where is energy being stored in this picture?

In the spring

Where do you see reaction forces in this picture?

The spring pushing on the ball and the ball pushing on the spring

What forces act on the projectile while it is in the air? Which way are they going?

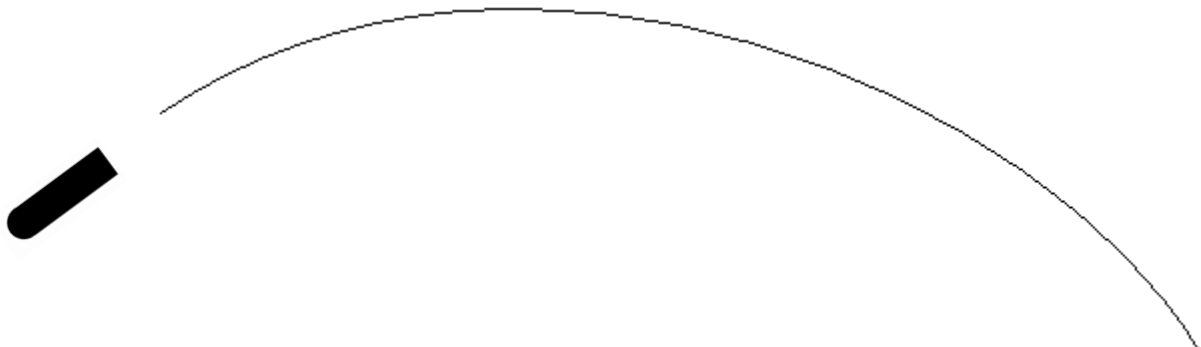
Gravity, downwards.

Air resistance, opposite the projectile's path

Here is what the path of the projectile should look like at a 30 degree angle and a medium power setting:

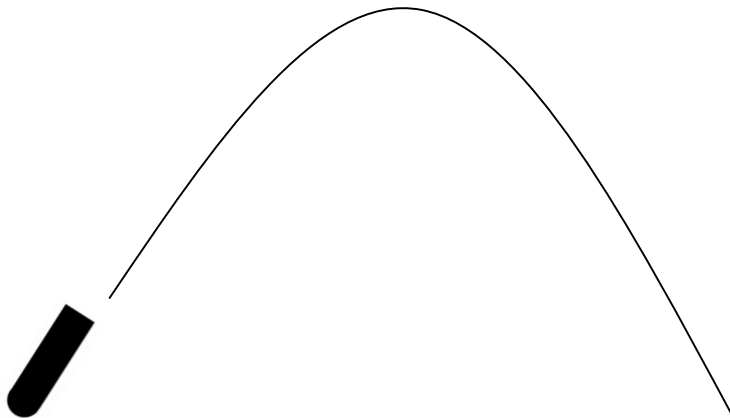


Draw what path you think the projectile will follow when it is shot from a higher starting position (hint: think about the Why Here? sign).



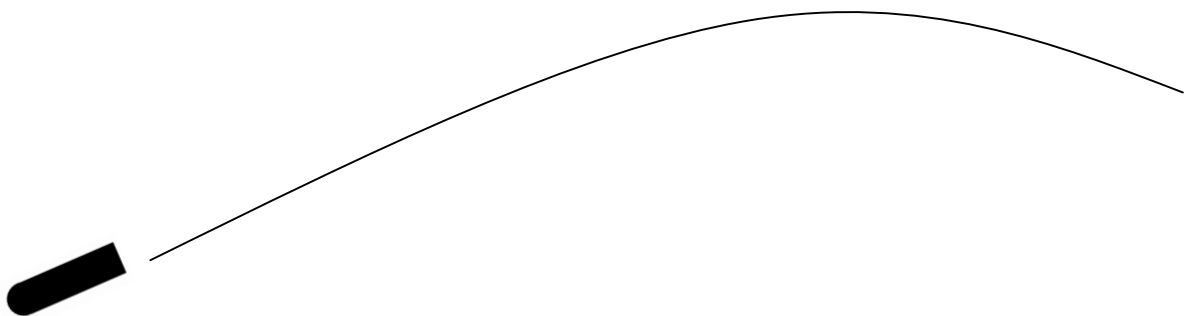
---

Draw what path you think the projectile will follow when it is shot at a higher angle setting (hint: think about the Newton Knew it sign).



---

Draw what path you think the projectile will follow when it is shot it with a higher power setting.



---

What do you think would happen if the following different kinds of ammo were shot from our cannon (hint: think about the Amazing Ammo sign)?

A heavy marble-

Shorter distance

A cotton ball-

Wouldn't launch very far

5 smaller masking tape balls all at once-

Spread out over a larger range. Not very precise

Why would we not use these to shoot from our cannon?

Not precise, wouldn't go as far

## Appendix P – Student Questionnaire

The questionnaire given out to the students after participating in the prototype session in order to collect feedback.

### Student Questionnaire

How many scavenger hunt questions did your group answer correctly?

Did your group get the ball in the castle? How many changes did it take?

Was there any part of the session that was confusing? Which part?

Pick a number 1-6 to answer the questions

How difficult were the exhibits for the scavenger hunt to find?

Too easy    1    2    3    4    5    6    Very hard

How hard were the questions in the scavenger hunt?

Too easy    1    2    3    4    5    6    Very hard

How hard was it to get the ball in the castle?

Too easy    1    2    3    4    5    6    Very hard

How much did the summary session help you to understand the science behind artillery?

Not much    1    2    3    4    5    6    A lot

## Appendix Q – Teacher Questionnaire

The questionnaire given out to the teacher's after having their students participate in the prototype session in order to collect feedback.

### Teacher Questionnaire

What science concepts would you like to be more emphasised in the session?

What concepts could use more time?

What concepts could use less time?

What concept in the session requires the most significant change in presentation? What can you recommend?

What materials for pre or post visit would make the session more effective for your students?

How would you like pre or post materials to be provided? (circle one)

Hard copy by post

Online on Royal Armouries website

E-mail

Pick a number 1-6 to answer the questions

How effective was your time at Fort Nelson in educating your students?

Not very      1      2      3      4      5      6      Excellent

How enjoyable was the session for your students?

Not very      1      2      3      4      5      6      Excellent

How effective was the scavenger hunt at reinforcing scientific facts for your students?

Not very      1      2      3      4      5      6      Excellent

How effective was the mini cannon shooting activity at getting students to understand scientific principles?

Not very      1      2      3      4      5      6      Excellent

How well did the summary section combine the ideas throughout the session?

Not very      1      2      3      4      5      6      Excellent

Would you recommend this session to other teachers?

## Appendix R – Questionnaire Rating Question Results

The results of the questions that can be rated quantitatively in the student and teacher questionnaires.

### Appendix R1 – Student Questionnaire Rating Question Results

#### Student

#### Questions:

- 1st col: How many scavenger hunt questions did your group get wrong?  
Did your group get the ball in the castle? How many changes did it take?
- Canon: take?
- Question 1, Q1: How difficult were the exhibits for the scavenger hunt to find?
- Question 2, Q2: How hard were the question in the scavenger hunt?
- Question 3, Q3: How hard was it to get the ball in castle?
- Question 4, Q4: How much did the summary session help you understand the science behind artillery?

#### Group 1 – 15 Students

Group1	Canon	Q1	Q2	Q3	Q4	
2	4	3	2	6	5	
0	5	3.5	4	5	6	
0	4	3.5	4	5	6	
0	5	3	4	5	6	
2	no	3	4	5	2	
3	4	3	4	5	2	
2	no	4	5	6	3	
0	no	2	1	6	6	
0	no	4	2	5	4	
0	no	5	2.5	6	5	
0	no	2	3	6	3.5	
0	5	2	4	5	5	
0	5	3.5	4	5	6	
2	4	3	4	5	5	
0	no	5	2	5	6	
<b>Avg</b>	<b>0.667</b>	<b>4.5</b>	<b>3.3</b>	<b>3.3</b>	<b>5.33333</b>	<b>4.7</b>
<b>Med</b>		4.5	3	4	5	5

**Group 2 –  
12 Students**

Group2	Canon	Q1	Q2	Q3	Q4	
0	4	2	3	3.5	3.5	
0	4	2	1	3	3	
1	2	3	4	3	3	
0	4	2	1	3	3	
0	4	2	1	3	3	
1	2	3	4	3	3	
1	2	2	4	3	3	
1	2	3	4	3	3	
0	no	3	2	5	2	
0	no	4.5	2	4	5	
0	no	4	4	5	3	
0	no	2	3	3	5	
<b>Avg</b>	<b>0.33333</b>	<b>3</b>	<b>2.70833</b>	<b>2.75</b>	<b>3.45833</b>	<b>3.29167</b>
<b>Med</b>		3	2.5	3	3	3

**Both Groups –  
27 Students**

Both	Canon	Q1	Q2	Q3	Q4
<b>Avg</b>	<b>3.75</b>	<b>3.03704</b>	<b>3.05556</b>	<b>4.5</b>	<b>4.07407</b>
<b>Med</b>	4	3	3	5	4

## Appendix R2 – Teacher Questionnaire Rating Question Results

### Teacher

#### Questions:

- Question 1, Q1: How effective was your time at Fort Nelson in educating your students?
- Question 2, Q2: How enjoyable was the session for your students?
- Question 3, Q3: How effective was the scavenger hunt at reinforcing scientific facts for your students?
- Question 4, Q4: How effective was the mini cannon shooting activity at getting students to understand specific principles
- Question 5, Q5: How well did the summary section combine the ideas throughout the session?

Teachers	Q1	Q2	Q3	Q4	Q5
<b>Group1</b>	5	6	4.5	4	4.5
<b>Group2</b>	4	5	3	5	3
<b>Avg</b>	<b>4.5</b>	<b>5.5</b>	<b>3.75</b>	<b>4.5</b>	<b>3.75</b>
<b>Med</b>	4.5	5.5	3.75	4.5	3.75



## **Appendix S – Student Questionnaire Open Response Results**

Results of the open response questions and extra comments the students added in their questionnaires.

### **Open Responses from Students**

*Was there any part of the session that was confusing? Which part?*

#### **Group 1**

- None
- When looking for the clues it wasn't obvious what they were
- Yes we weren't quite sure what we were looking for at the beginning
- Yes, when looking for the clues
- Yes, the hints
- Some of the signs
- No it was ok, just some signs
- The mass question
- One of the questions was really confusing (mass matters)
- The introductions because I didn't understand how if you answered so many questions how does it affect how many times you could shoot or change it
- Some of the clues weren't worded properly
- At the beginning you didn't know what the clues looked like
- When you went on the scavenger hunt you didn't know what the clues looked like, so you didn't know quite what you were looking for
- The signs with the questions
- The questions weren't in order of where they were

#### **Group 2**

- Yes, questions 7 artillery hall. It was difficult, and we were not even allowed help from the people, even the teacher didn't know
- Yes the difference between the mass and the weight on question

- No not really
- Difference between mass and weight
- The difference between mass and weight, question 7
- No
- -
- No not really
- None
- No not really
- No
- No not really

*Other Comments from Students*

**Group 1**

- We need a bigger map
- We need a bigger map, we almost got lost
- Bigger map & clearer and instructions on sheet
- Needed a bigger and easier map and need to make sure the cannons worked
- We need a bigger map so you know where to go and can find your way
- I think that the students could have helped out a bit more

**Group 2**

- We found out at the gun shooting, that the light travels faster than the sound, but perhaps not anything else
- I did find a few things that I already know, but most of the things I found out I never knew before
- I did not know that there was so much science in artillery. Light also travels faster than sound
- Light travels faster than the bang
- Do a scavenger hunt that is funner and better things to find
- Make the answer harder to make out than just copying down
- Add tunnels to the scavenger hunt

## Appendix T - Open Responses from Teachers

Results of the open response questions and extra comments the teachers added in their questionnaires.

Teacher of the First Group of Students - #1

Teacher of the Second Group of Students - #2

*What science concepts would you like to be more emphasised in the session?*

1. Controlling variables one at a time to find the effect
2. Acceleration, speed, momentum (more suitable for KS4), or materials suitable for artillery

*What concepts could use more time?*

1. Mass + Weight
2. Gun firing, speed of sound & light. Differentiation, catapult/trebuchet, maybe design one!

*What concept in the session requires the most significant change in presentation? What can you recommend?*

1. Trajectory – visual representation to compare angles
2. Not really, but the explanations for the question were too direct!

*What materials for pre or post visit would make the session more effective for your students?*

1. –
2. None, it was all well communicated in plenty of time

Both would prefer post materials via email

*Would you recommend this session to other teachers?*

1. Yes – especially if combined with other activities i.e. “materials” in some kind of circus so larger groups could attend
2. Yes, without a doubt

### **Other comments:**

1. All from first teacher
  - A little more time on concepts before starting to decide on settings. More changes available (2 per question?)
  - Felt like a race so less time thinking about the concepts. Might put key ideas/answers in bold or colour for weaker pupils
  - More time for cannon activity
  - Summary section was rushed

## Appendix U – Online Teacher Survey

The questions asked for the teachers who took the online teacher survey about educational science sessions.

1. What age are your students?
  - a) 4-6
  - b) 7-10
  - c) 11-14
  - d) 15-18
2. Have you ever brought your students to a museum science session?
  - a) Yes
  - b) No
3. Are there museums with educational site sessions in your area?
  - a) Yes
  - b) No
4. Do your students have any special needs? If yes, please explain how their program differs from the general curriculum.
5. Have your students experienced the following science learning techniques? Check all that apply.
  - a) Scientific Method
  - b) Laboratory Work
  - c) Group Discussions
  - d) Real World Applications
6. What outcomes would you like the students to achieve during a museum science session?
7. Would you be interested in bringing your students to a science based session at Fort Nelson? Why or why not?

## Appendix V – Online Teacher Survey Results

The results of the online teacher survey.

*Questions from survey in italics*

**Number of responses and written responses in bold**

1. *What age are your students?*

- a) 4-6 **(4)**
- b) 7-10 **(11)**
- c) 11-14 **(9)**
- d) 15-18 **(4)**

2. *Have you ever brought your students to a museum science session?*

- a) Yes **(11)**
- b) No **(11)**

3. *Are there museums with educational site sessions in your area?*

- a) Yes **(20)**
- b) No **(1)**

4. *Do your students have any special needs? If yes, please explain how their program differs from the general curriculum.*

- **BESD pupils**
- **Fully integrated students with cerebral palsy. They are supported by LSA's within the classroom.**
- **Yes. More adult help requested**
- **Behaviour – 1 to 1 adult supervision. Physical disabilities – wheelchair access. Visual impairment – large print**
- **Mobility – not too many steps/uneven surfaces**
- **Several – al accessing the curriculum at different levels, and some children still working off the Foundation Stage Profile**

- **Hearing – integrated through specialist unit, support in mainstream**
- **Some autistic children and behavioural problems. Some poor academic progress**
- **No difference to programme, bar assistants helping with e.g. lighting Bunsen burners due to less dexterity in hands**
- **Some do...cerebral palsy, needs access because of physical disabilities also a lot of work is done using lct as he has very little fine motor control.**
- **Complex SEBD pupils who have individually-tailored lessons to meet their specific needs.**
- **Less able, shorter concentration poor verbal skills**
- **All children access the general curriculum however some of them need support in explaining instructions clearly and how to use equipment safely for this reason some children have 1:1 support.**
- **Differentiation as and when required**
- **Yes, pretty much the same more doing BTEC than GSCE.**

5. *Have your students experienced the following science learning techniques? Check all that apply.*

- a) *Scientific Method (19)*
- b) *Laboratory Work (10)*
- c) *Group Discussions (18)*
- d) *Real World Applications (15)*

6. *What outcomes would you like the students to achieve during a museum science session?*

- **Standard KS3 outcomes i.e. alloys used in gun making, forces, how weapons work, recoil**
- **Total involvement, stimulation to find the new information and consider the importance of the big ideas and their applications in everyday life.**
- **To cover aspects of their science units they cover at school**
- **A sense of wonder. Excitement about science**

- **Enrichment. Enthusiasm.**
- **Learn new information. Take part in activities they wouldn't be able to do in the classroom**
- **It depends what it is they're doing. I'd like children to use discussion skills and to access the curriculum at a suitable level in each session. I'd like the children to be inspired/engaged enough to independently follow up an activity and to gain new skills that can be applied to all areas of the curriculum.**
- **Any as long as session is practical**
- **Hands on. Real life context. Fun.**
- **Enjoyment and sense they have learnt something**
- **Hands on, practical science. Something that we would not normally be able to do with in the classroom environment. Exciting science!! To get them hooked!**
- **Learn about our world and its complexities in a fun and interesting way which has value and meaning for them with their respective conditions**
- **To be inspired and to be able to relate the scientific process to the real world**
- **Fun and learn something**
- **Excitement and WOW**
- **Relate it to the real world, links with the science curriculum, be enthusiastic about science, increase curiosity.**
- **What exactly is being offered? A lot of assessment based on how science works so what can the museum offer?**
- **Interactive activity, teaching a concept we would find it difficult to teach in school.**
- **Better understanding of application of science. More enthused and motivated to study science.**
- **Firsthand experience**

7. *Would you be interested in bringing your students to a science based session at Fort Nelson? Why or why not?*

- **Yes**
- **Yes but distance and cost of transport. Having time out from school is increasingly difficult as cover implications and costs are prohibitive**
- **Yes**
- **Yes. Our main limitation is the cost. Very few of our parents are willing to pay towards school trips and our budget is very tight. It is not easy to argue your case for a museum visit.**
- **Yes**
- **Yes**
- **Yes, but often our parents cannot afford visits as a coach is costly.**
- **Cost involved in transport too high as north of the county**
- **My class this year are 4 and 5 so it is probably a bit far for them to travel but maybe the older children**
- **Already have!**
- **Possibly...depends on cost, transport issues and whether it linked to the curriculum work they are doing. Also wheelchair access.**
- **Yes. Been before usually with small groups (6 max) but often 1:1**
- **If it “fitted” in with our curriculum and was not too expensive as budgets are tight.**
- **Depends on what was an offer and how much – transport is a big issue for us**
- **Definitely. They learn so much more from real life context**
- **Yes but depends when current year group is already booked on a history visit however it could be passed to a different year.**
- **Sounds good in theory but I don’t want to do all the planning for a trip re: health and safety or book transport tec. Also it’s very hard to get cover for teachers on trips**
- **Depends on school policy about number of trips allowed out**
- **Yes**
- **Transport costs are our biggest bugbear**



## Appendix W - Cannon Construction Instructions

Instructions to build the cannon used in the miniature cannon activity.

# Miniature Cannon Construction Instructions

All dimensions in **cm** unless otherwise specified

### Materials:

1 small flush hinge (and screws that come with)

1 flush hinge (and screws that come with)

1 corner bracket

1 rivet

1 M6 bolt length 100mm

2 M10 washers

2 M6 65mm bolts

2 M6 nuts

5 M6 washers

Medium density fibre board (MDF) 10mm thick

Spring model S.622 from Ashfield Springs

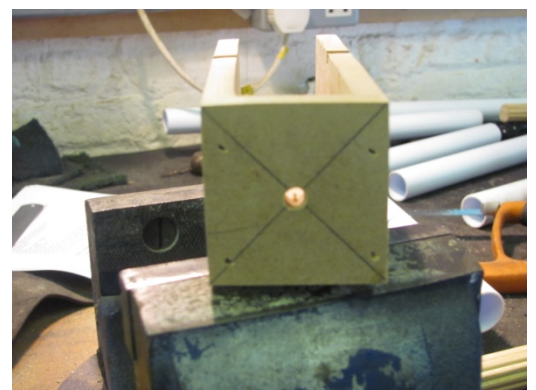
PVC tubing of 32mm inner and 35mm outer diameters

Wood doweling of diameter 25mm

### Inner Housing:

2 rectangular side walls  
13.5x5.5

1 rectangular base  
13.5x3.5

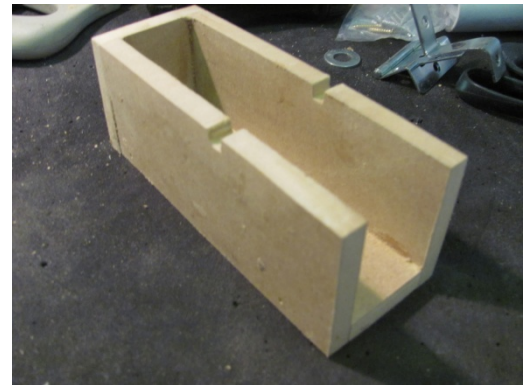


1 square back wall, side length 5.5

- Drill a hole directly in the middle of diameter 7mm

Subassembly:

- Attach the side walls to the sides of the rectangular base (either with wood glue or small nails)
- Attach the back wall (in a similar manner)
- File an indentation in the top of the side walls large enough for the pivot of the flush hinge to fit into, beginning a distance of 8.5 from the very back end of the housing

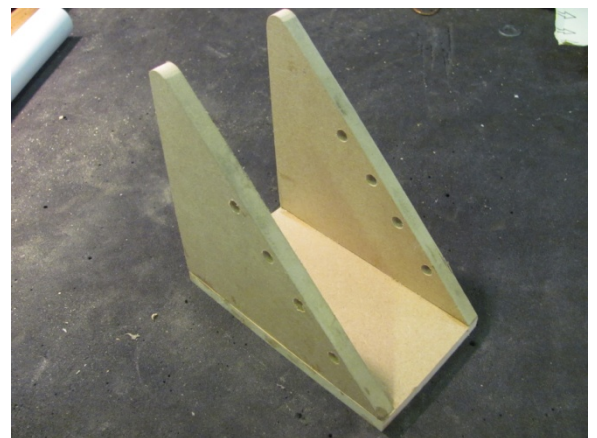


## Outer Housing:

1 rectangular base 14.5x8.5

2 isosceles right triangles, side length 14.5

- Round one of the acute angled corners on each
- Drill holes in the side walls of diameter 7mm either using existing cannon as a template or if unavailable they make 15, 30, 45, and 60 degree angles (from the right angled corner, with the rounded corner pointing up):

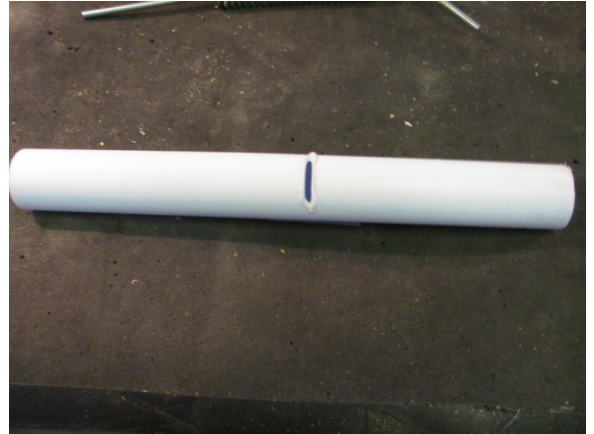


Subassembly:

- Attach the triangular pieces atop the base on opposite sides (either with wood glue or small nails)

### Barrel:

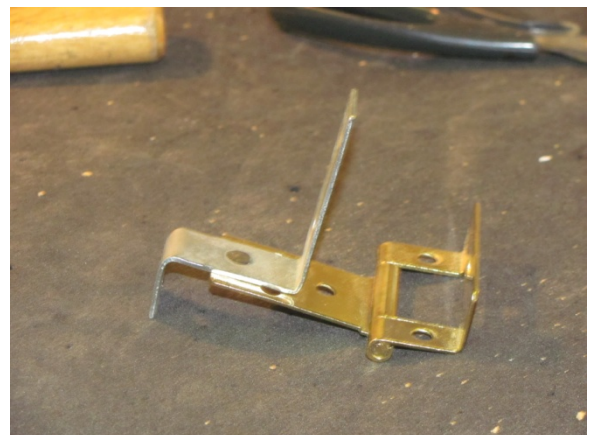
- Cut PVC tubing to length 30
- File slot in barrel beginning 13.5 from an end of length .5 wide enough for the firing mechanism to fit through easily
- Clean the cut to assure that the barrel is clear



### Firing Mechanism:

Subassembly:

- Rivet the corner bracket to the flush hinge such that the angle faces directly away from the pivot
- Bend the arm of the corner bracket at 3.5 from the corner to a right angle



## Spring Mechanism:

Spring cut to length 13

2 Dowel sections cut to lengths 1, and one of length 3

- Drill holes of diameter 6mm through the centre of the dowel



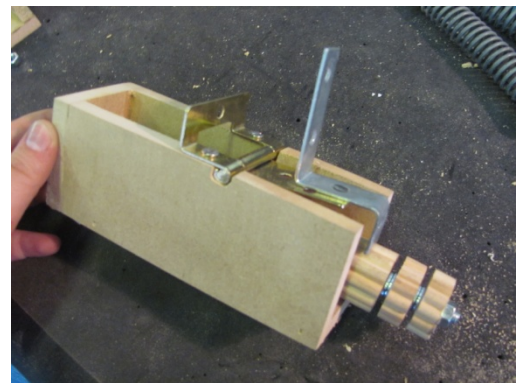
sections

Subassembly:

- Insert the M6 65mm bolt into the M10 washer and weld the washer to the end of the spring such that the bolt head is inside the spring
- Repeat on the other end of the spring
- Place these pieces onto the bolt on one end of the spring in the following order:
  - 3 length dowel section
  - 2 M6 washers
  - 1 length dowel section
  - 2 M6 washers
  - 1 length dowel section
  - 1 M6 nut
- Tighten down the nut

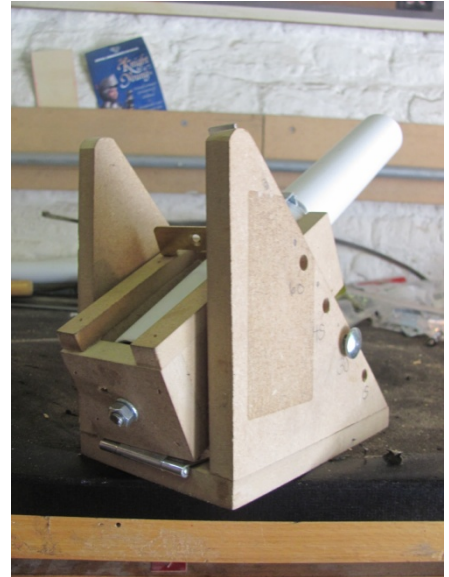
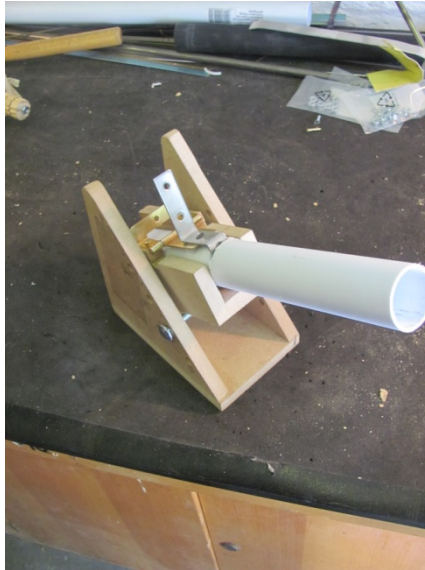
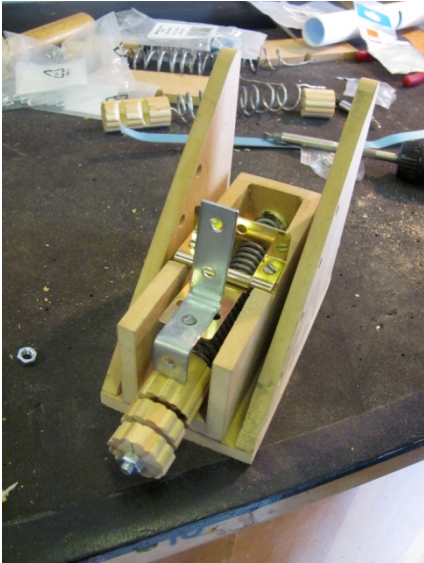
## Final Assembly:

- Insert the bare bolt of the spring mechanism into the hole in the back of the inner housing
- Place a M6 nut on the bolt from behind the back wall of the inner housing
- Thread a M6 nut all the way down the bolt
- Cut off the remaining portion of the bolt behind the nut
- Attach the firing mechanism to the inner housing with the pivot in the indentation on the top of the inner housing (pre drill the screws as the wood will split)
- Attach the inner housing to the outer housing with the small hinge such that the pivot hangs over the back of the outer housing base and that the inner housing does not touch either side of the outer housing (pre-drill the screws as the wood will split)
- Slide the barrel down over the spring mechanism with the end that is closer to the hole in the side of the barrel pointing toward the back wall with the hole facing upwards until it touches the back of the inner housing (it should be a tight fit)





- Insert the 100mm bolt through one set of holes on the outer housing so that the inner housing rests on the bolt (the bolt should be removable)



### **Additional Materials:**

Masking tape

Wood dowel (smaller diameter than the barrel but stiff)

### **Cannon shots:**

Ball the tape into a tight ball assure the adhesive side is in the middle until the diameter is approximately 25mm

### **Cannon loading rod:**

Cut the dowel to length 40 and sand any rough edges

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