ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL ONE

INSTRUCTIONAL GUIDE

SECTION 1

EO M140.01 – LAUNCH A WATER ROCKET

Total Time: 90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-801/PG-001*Proficiency Level One Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy and prepare Water Rocket Launch System; see instructions located at Attachment A, if required.

Prepare a Water Rocket launch site; see instructions located at Attachment B.

Practice assembling the Water Rocket launch System and launching water rockets before this lesson.

Water Rocket Safety Orders are located at Attachment C.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TP 1 to orient the cadets to Newton's Laws of Motion.

An in-class activity was chosen for TP 2 as a fun way to have the cadets launch a water rocket in a safe and controlled environment.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet will have launched a water rocket.

IMPORTANCE

This lesson will demonstrate for the cadets Newton's Laws of Motion and they will this in action when they launch a water rocket.

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Teaching point 1 **Explain and Discuss Newton’s Three Laws of Motion.**

Time: 15 min Method: Interactive Lecture

Newton’s Laws of Motion

The three laws of motion were first compiled by Sir Isaac Newton in his work *Philosophiæ Naturalis Principia Mathematica*, first published on July 5, 1687. Newton used them to explain and investigate the motion of many physical objects and systems.

Newton's laws of motion are three physical laws that form the basis for classical mechanics. They describe the relationship between the forces acting on a body and its motion due to those forces. A force can be defined as a push or a pull on an object.



Demonstrate force by pushing and pulling an object (book, pen, etc.) in a straight line across a flat surface.

Newton’s First Law of Motion, or the Law of Inertia.

Newton's first law states that every object remains at rest or in uniform motion in a straight line until an external or internal force is applied to the object. This is also the definition of inertia.

Inertia is the resistance of any physical object to a change in its state of motion or rest, or the tendency of an object to resist any change in its motion.



Point to a movable object at rest. The object is following Newton’s First Law of Motion.

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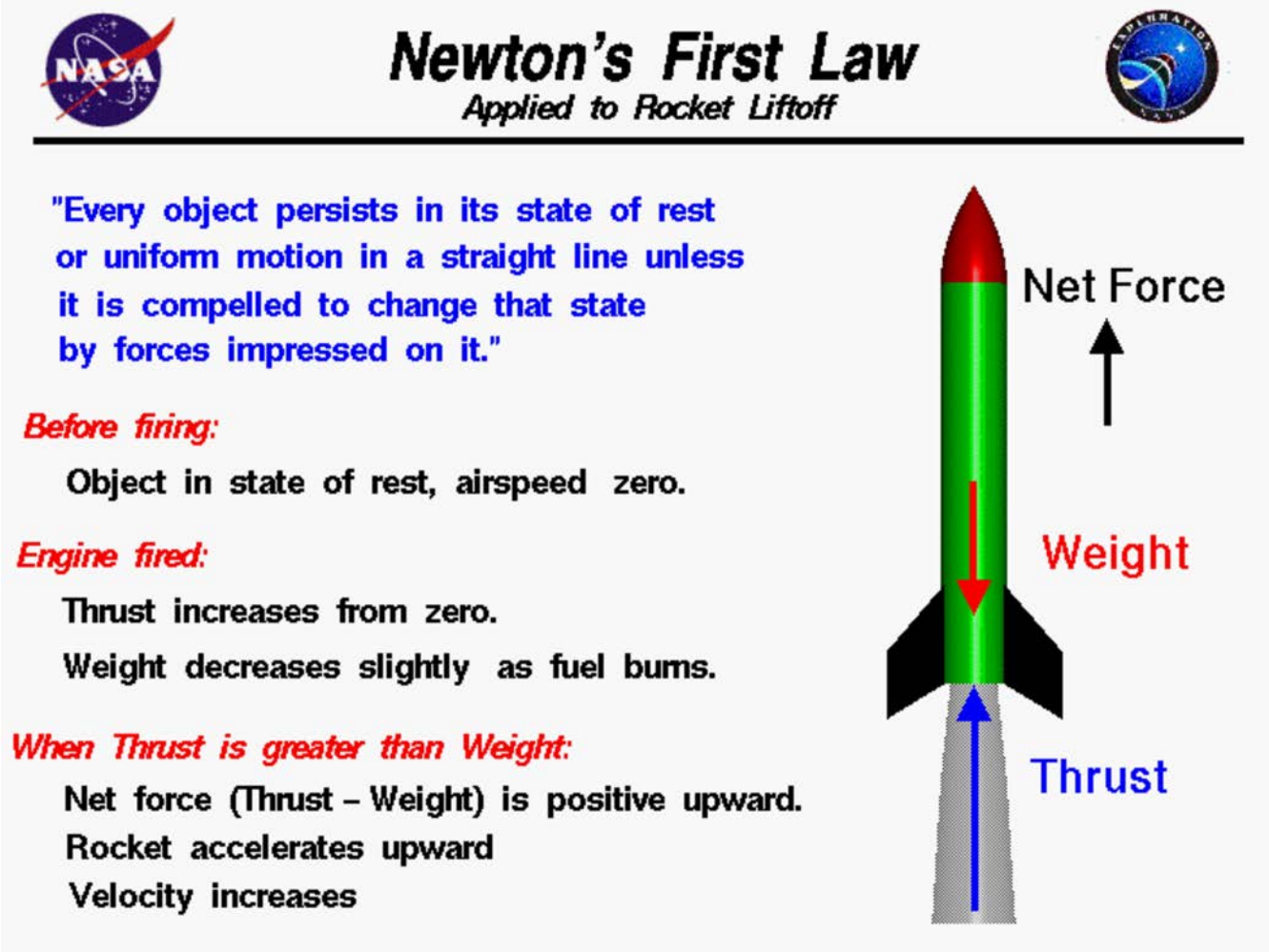

Note: From NASA (2011). Newton's First Law. Retrieved December 7, 2011 from http://exploration.grc.nasa.gov/education/rocket/newton1r.html

Figure 1 Newton's First law

If there is no force acting on an object then the object maintains a constant velocity. If that velocity is zero, then the object remains at rest. If an external force is applied, the velocity changes because of the external force.

Constant velocity can only happen in a vacuum like space. On Earth, air and / or gravity creates resistance or friction, slowing the object down.

This first law gives a frame of reference for the other laws of motion by establishing that an object at rest or in motion can have its state of rest or motion altered by external or internal forces.

Examples of this Law are:

- The pen placed on a flat level desk will not move as the forces of friction and gravity are acting on it.
- A satellite in outer space continues on its trajectory unless the gravity of an object it passes alters its trajectory.
- The Water Rocket on the Launch Tower will not move (other than a slight wobble due to air resistance from wind) as gravity keeps it on the launch tower until it is pressurized and launched.

Newton's Second Law of Motion

Newton's second law of motion explains how an object changes velocity if external forces are applied to it.

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1. The law states that if a force is applied to an object, it accelerates or changes its velocity, and it changes its velocity in the direction of the force.



An object accelerates in the direction that the force is applied.

2. The acceleration is directly proportional to the force applied. If an object is pushed, it causes it to accelerate. If the object is pushed three times harder, the acceleration is three times greater.

3. The acceleration is inversely proportional to the mass of the object. If two objects are pushed equally, and one of the objects has five times more mass than the other, it accelerates at one fifth the acceleration of the other.



If the mass of an object increases, the acceleration decreases proportionately.

Some of the forces that can change an objects state are:

- gravity,
- air resistance,
- friction,
- external or internal force.

A formula to help explain this is:

F=*m*a

Where F is equal to the force, measured in Newton Metres and m is equal to the mass of the object. A is equal to the acceleration of the object.

Rockets during launch burn some of their propellant and therefore become lighter, changing their mass. As the rocket mass changes or becomes lighter, and the rocket engine continues to produce the same amount of thrust, the rocket accelerates.

Newton's Third Law of Motion

Newton's Third Law of Motion states that for every action or force in nature there is an equal and opposite reaction. This force is proportionate to the mass of the objects involved

When the trigger is pulled on a firearm, the gunpowder explodes, pushing the projectile or bullet out of the barrel. The force applied to the projectile is the same as the force applied to the firearm. The mass of the firearm is less than the mass of the projectile resulting in less force applied to the shooter.

A rocket engine forces gasses or propellant out its nozzle, pushing the rocket in the opposite direction.

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CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What is Newton’s First Law of Motion?

Q2. What is Newton’s Second Law of Motion?

Q3. What is Newton’s Third Law of Motion?

ANTICIPATED ANSWERS:

A1. Newton's first law states that every object remains at rest or in uniform motion in a straight line until an external or internal force is applied to the object.

A2. Newton's second law of motion explains how an object changes velocity if it is pushed or pulled upon.

A3. Newton’s Third Law of Motion states that for every action or force in nature there is an equal and opposite reaction.

Teaching point 2 **Have the cadets launch a water rocket.**

Time: 65 min Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to demonstrate Newton’s Laws of Motion in a dynamic and interesting way.

RESOURCES

- An outdoor area 10 by 20 square metres,
- A water rocket launch system,
- A pump to supply compressed air to the launch system (a bicycle pump or tire inflator is best)
- A two litre soda bottle in good condition (no deep scratches or obvious defects). Only use carbonated drink type bottles. Water bottles are not strong enough to be used on a pressurized system,
- Safety glasses one per cadet instructors, and
- Water to launch the water rocket several times.

ACTIVITY LAYOUT

Setup the launch site using the instructions included in Attachment B.

Brief the cadets as per Attachment B Launch Site Setup.

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ACTIVITY INSTRUCTIONS



For both launches use the same air pressure, 50 to 60 Psi. For the first launch, load the 2 litre soda bottle onto the launch system without water in it to demonstrate thrust with air as the propellant mass.

1. Mount the empty two-litre soda bottle on the water rocket launch tower.

2. Explain to the cadets that the bottle is demonstrating Newton's First Law of Motion as it is stationary and the only force currently applied is gravity.

3. Pressurize the launch tower to 50 to 60 psi.

4. Have the cadets count down from five and launch the soda bottle.



The force of the air escaping from the soda bottle pushes the bottle into the air. This demonstrates two of Newton's Laws of Motion.

The First Law of Motion is demonstrated as the rocket is at rest on the tower.

The Second Law of Motion is demonstrated as the rocket lifts off. The force of the air escaping pushes the bottle in a linear direction off the launch tower.

The Third Law of Motion is demonstrated as the reaction of the air being pushed out of the bottle forces it away from the launch tower.

5. Recover the soda bottle and fill it one third full with water.

6. Reload the soda bottle onto the launch tower.

7. Pressurize the launch tower to the same pressure as the empty bottle launch.

8. Have the cadets count down from five and launch the water rocket.



For the second launch, load the two litre soda bottle onto the launch system after filling it one third full with water to demonstrate thrust with water as the part of the propellant. The mass of the bottle with the water in it slows the rocket down on launch, but the mass of the water being forced out of the bottle pushes the bottle much higher. As the bottle gets lighter, it accelerates faster until the propellant and pressure diminish. Even after the water has evacuated the bottle, the air pressure left in the bottle continues to provide thrust to the bottle until it is exhausted.

9. Have the cadets discuss the difference between the two launches.

SAFETY

Water Rocket Safety Orders are located at Attachment C.

END OF LESSON CONFIRMATION

The cadets' participation in the activity will serve as the confirmation of this lesson.

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CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

Nil.

CLOSING STATEMENT

Newton's Laws of Motion apply to everything around us. In rocketry, these laws govern the entire flight profile of a rocket before, during and after launch.

INSTRUCTOR NOTES / REMARKS

Cadets qualified as Advanced Aerospace may serve as assistant instructors.

The water rockets may be launched indoors in an area easy to clean up (eg, gymnasium floor) or out of doors in favourable weather.

REFERENCES

C3-266 Science Toy Maker. (2008). Making (and using) an overhead water rocket launcher. Retrieved October 1, 2008, from http://www.sciencetoymaker.org/waterRocket/buildWaterRocketLauncher.htm

C3-291 Retter, Y. (2008). *Water Rocket – Skewer Design*. Retrieved November 21, 2008, from http://www.geocities.com/yoramretter/SkewerDesign-v02.html

C3-351 National Aeronautics and Space Administration. (2008). *Adventures in Rocket Science*. Retrieved October 27, 2011, from http://www.nasa.gov/pdf/265386main_Adventures_In_Rocket_Science.pdf

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CONSTRUCTING A WATER ROCKET LAUNCH SYSTEM

Material List

Quantity	Part No.	Item	Length
1	A1	½-inch CPVC tube	7 inches
1	A2	¾ x ½ CPVC reducer	
1	A3	¾-inch CPVC tube	40 inches
1	A4	¾-inch female CPVC adapter	
1	A5	¾-inch male CPVC adapter	
1	A6	¾-inch CPVC tube	3 inches
1	B1	tire stem valve (for a ½-inch hole)	
2	B2, C1	¾-inch CPVC end cap	
2	B3,C2	¾-inch CPVC tube	24 inches
2	B4, C3	¾-inch CPVC T-joint	
1	B5	¾-inch CPVC tube	19 inches
1	B6	¾-inch CPVC ball valve	
1	C4	¾-inch CPVC tube	7 inches
1		8 x 2 inch sticky (Duct) tape	
10		6 to 7 inch long cable ties	
1		¾-inch O-ring, or soft hose washer	
2		#12 steel hose clamp	
1		1¼-inch ABS coupler	
1		braided string	
1		2-litre soda bottle	
1		CPVC Cement	
1		CPVC Solvent / Cleaner	
1		Heavy weight (eg. sand bag)	

One 10 foot length of ¾ inch CPVC schedule 40 tube will build one launch system.

7 inches of ½ inch CPVC tube is required for the bottle guide for each launch system.

Only use PET plastic soda bottles designed for carbonated drinks in good condition. Do not substitute a water PET bottle for a soda bottle. Bottles with deep scratches, hard creases, or more than 10 pressurized launches will not be used. Indicate the number of launches on the bottle with an indelible marker. Do not use sandpaper, hot melt glue, solvent based glue or any other chemical or heat that may weaken the soda bottle.

The launch system will be able to launch 500 millilitres to 2 litre carbonated soda bottles.

Tool list

Pliers,

Saw,

Scissors,

Drill,

Drill bits for ½ inch and 1/8 inch holes,

Hand file, and

Source of compressed air with a gauge (eg. bicycle pump, tire inflator or compressor).

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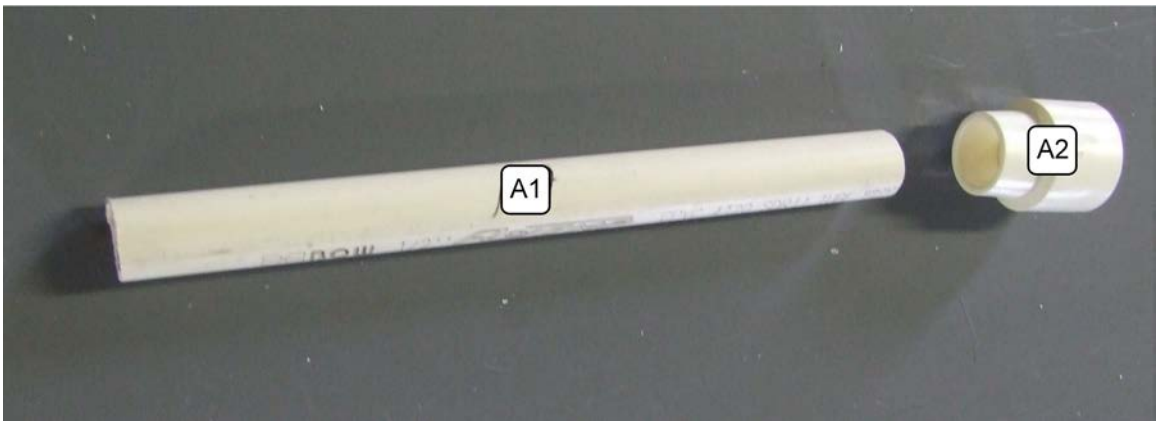
Assembling the Water Rocket Launch System

The launch system will be assembled in 3 sections of tubing, and a bottle clamp and release system

Section A

Section A consists of:

- A1 – ½-inch CPVC tube, 7 inches
- A2 – ¾ x ½ CPVC reducer



Note. Created by Director Cadets 3, 2011, Ottawa, ON: Department of National Defence.

Figure A-1 Section A, A1 and A2

- A3 – ¾-inch CPVC tube, 40 inches
- A4 – female ¾-inch CPVC adapter
- A5 – male ¾-inch CPVC adapter
- A6 – ¾-inch CPVC tube, 3 inches



Note. Created by Director Cadets 3, 2011, Ottawa, ON: Department of National Defence.

Figure A-2 Section A: A3, A4, A5 and A6

Section B

Section B consists of:

- B1 – tire valve stem
- B2 – ¾-inch CPVC end cap
- B3 – ¾-inch CPVC tube, 24 inches
- B4 – ¾-inch CPVC T-joint

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- B5 – ¾-inch CPVC tube, 19 inches
- B6 – 1 ¼-inch CPVC ball valve

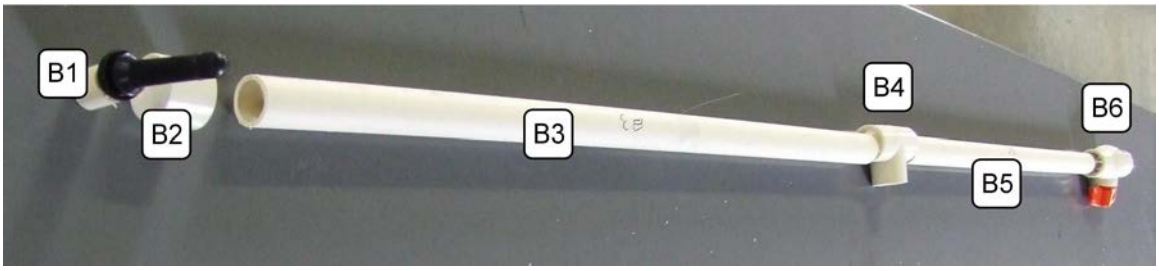

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Figure A-3 Section B: B1, B2, B3, B4, B5, and B6

Section C

Section C consists of:

- C1 – ¾-inch CPVC end cap
- C2 – ¾-inch CPVC tube, 24 inches
- C3 – ¾-inch CPVC T-joint
- C4 – ¾-inch CPVC tube, 7 inches

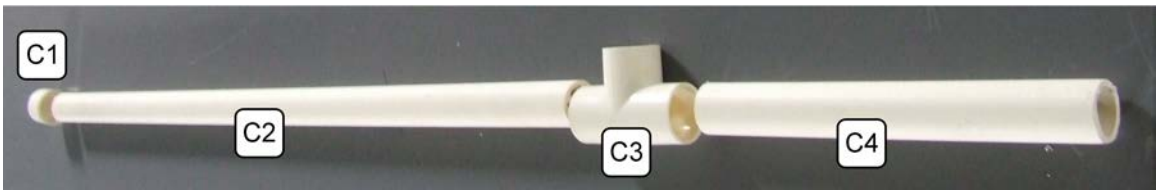

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Figure A-4 Section C: C1, C2, C3 and C4

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Cut the ¾-inch CPVC pipe as close to 90 degrees as possible. This allows the most glue surface area possible, and makes a solid reliable join.



Deburr the cut edges with a file or sandpaper and when gluing the pieces together, clean all joint surfaces with CPVC Solvent / Cleaner before gluing.



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Figure A-5 Deburring the end of the tube with a hand file.

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When gluing, apply CPVC Cement to both ends to be joined, join ends and twist joint clockwise until resistance is felt. Use only enough glue to coat the two parts. Avoid excess glue as this can melt the inside of the tube or fitting, weakening it. The cement sets in less than 30 seconds so be sure to align the parts quickly and accurately.



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Figure A-6 Applying cleaner or glue to the joint surfaces before gluing.

Building Directions

Section A

Apply CPVC Cement and join:

- bottom part A1 (½-inch CPVC tube, 7 inches) to A2 (½-inch end of ¾ x ½ inch CPVC reducer);

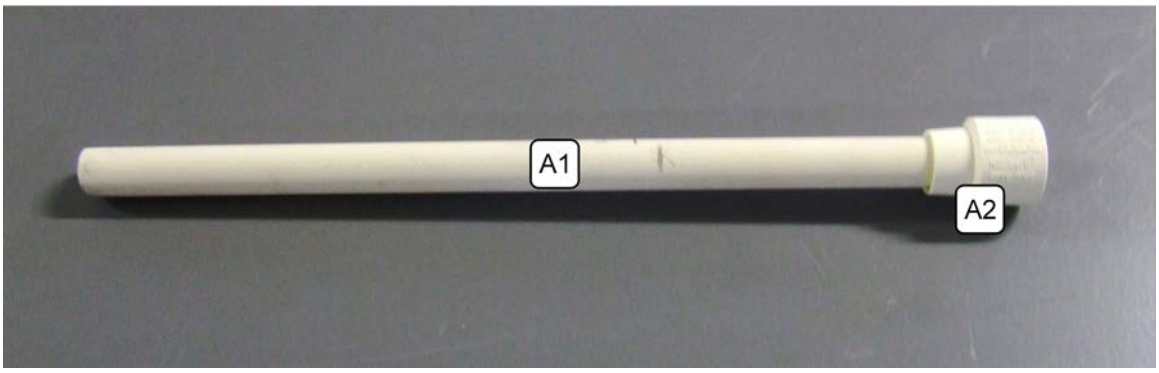

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Figure A-7 Section A, A1 and A2

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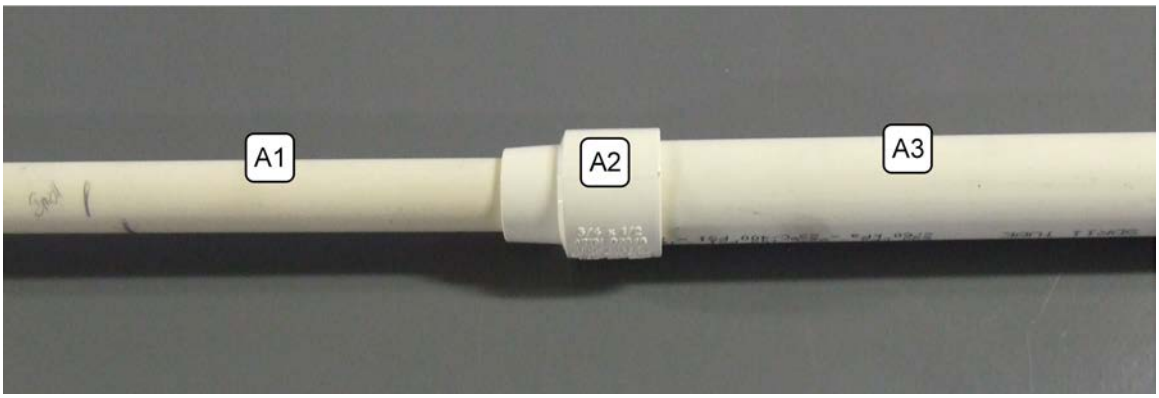
- A2 (¾-inch end of ¾ x ½ inch CPVC reducer) to A3 (¾-inch CPVC tube, 40 inches);



Note. Created by Director Cadets 3, 2011, Ottawa, ON: Department of National Defence.

Figure A-8 Section A, A1, A2 and A3

- A3 ¾-inch CPVC tube, 40 inches) to A4 (¾-inch female CPVC adapter); and



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Figure A-9 Section A, A3 and A4

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- A6 (¾-inch CPVC tube, 3 inches) to A5 (¾-inch male CPVC adapter).

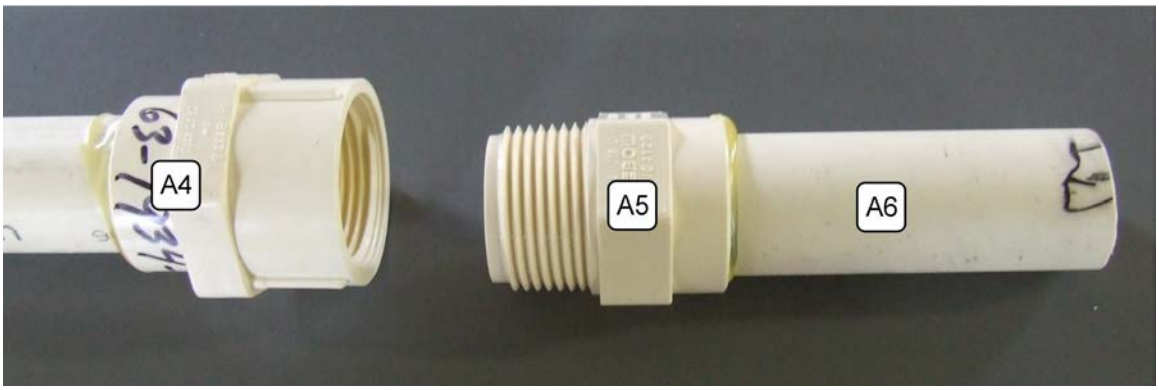

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Figure A-10 Section A, A4, A5 and A6



Do not allow glue to touch the threaded portion or the gasket surfaces of A4 (¾-inch female CPVC adapter) and A5 (¾-inch male CPVC adapter).



Use the male / female adapter joint to disassemble the water rocket launcher for transport and storage.

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Section B

Prepare B2 (¾-inch CPVC end cap) for the tire valve stem:

- Drill a ½ inch hole in B2 (¾-inch CPVC end cap). Drill at a slow speed and hold the end cap in a vise or pair of pliers.



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Figure A-11 Section B, Drilling the hole for the tire valve stem.

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- Pull B1 (tire valve stem) through the ½ -inch hole from the inside in B2 (¾-inch CPVC end cap) until the valve stem is seated on the end cap.



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Figure A-12 Section B, Tire Valve Pulled Through B2

Apply CPVC Cement and join:

- B2 (¾-inch CPVC end cap with tire stem valve) to B3 (¾-inch CPVC tube, 24 inches);

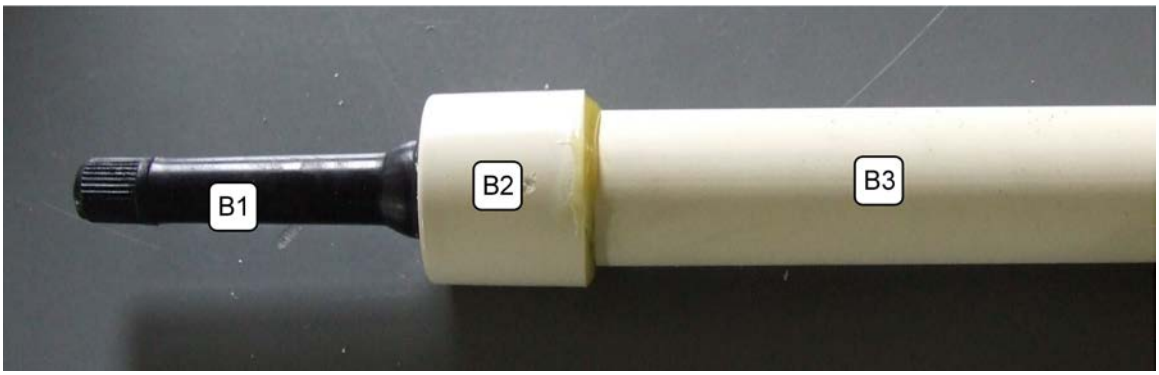

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Figure A-13 Section B, B1, B2 and B3

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- B3 (¾-inch CPVC tube, 24 inches) to B4 (¾-inch CPVC T-joint);
- B4 (¾-inch CPVC T-joint) to B5 (¾-inch CPVC tube, 19 inches); and

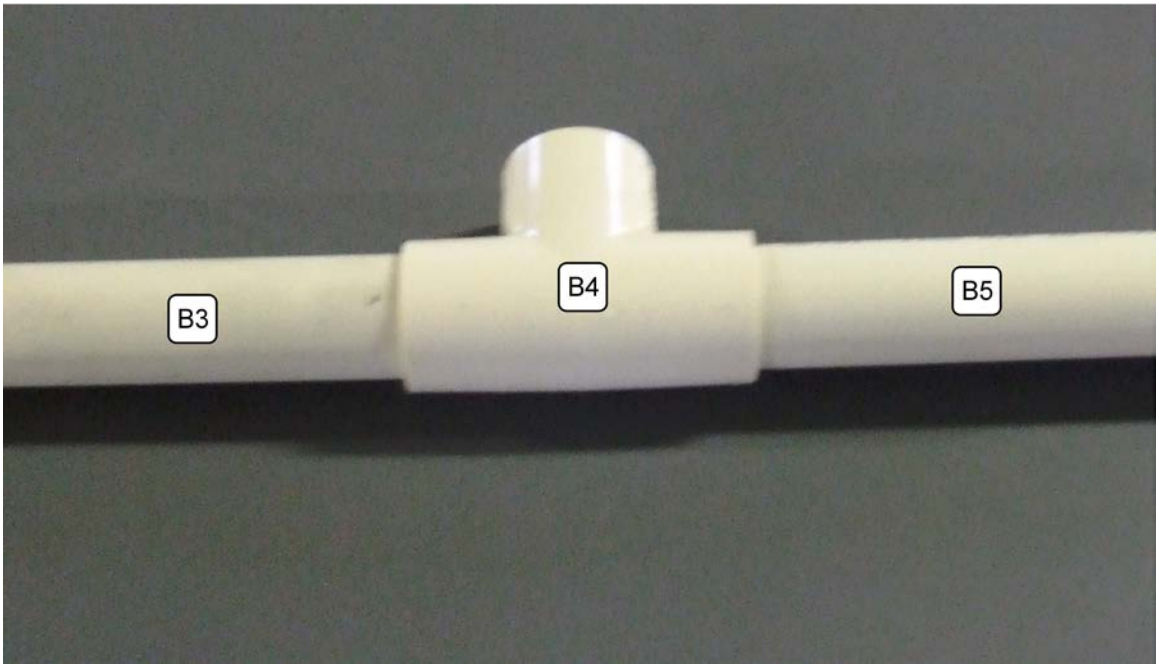

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Figure A-14 Section B, B3, B4 and B5

- B5 (¾-inch CPVC tube, 19 inches) to B6 (¾-inch CPVC valve). Ensure that the valve handle is clocked 90? to B4 (¾-inch CPVC T-joint).

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Clocking is aligning the parts along their centre axis. The handle of B6 (¾-inch CPVC valve) points vertically and the open centre female connection of B4 (¾-inch CPVC T-joint) points horizontally

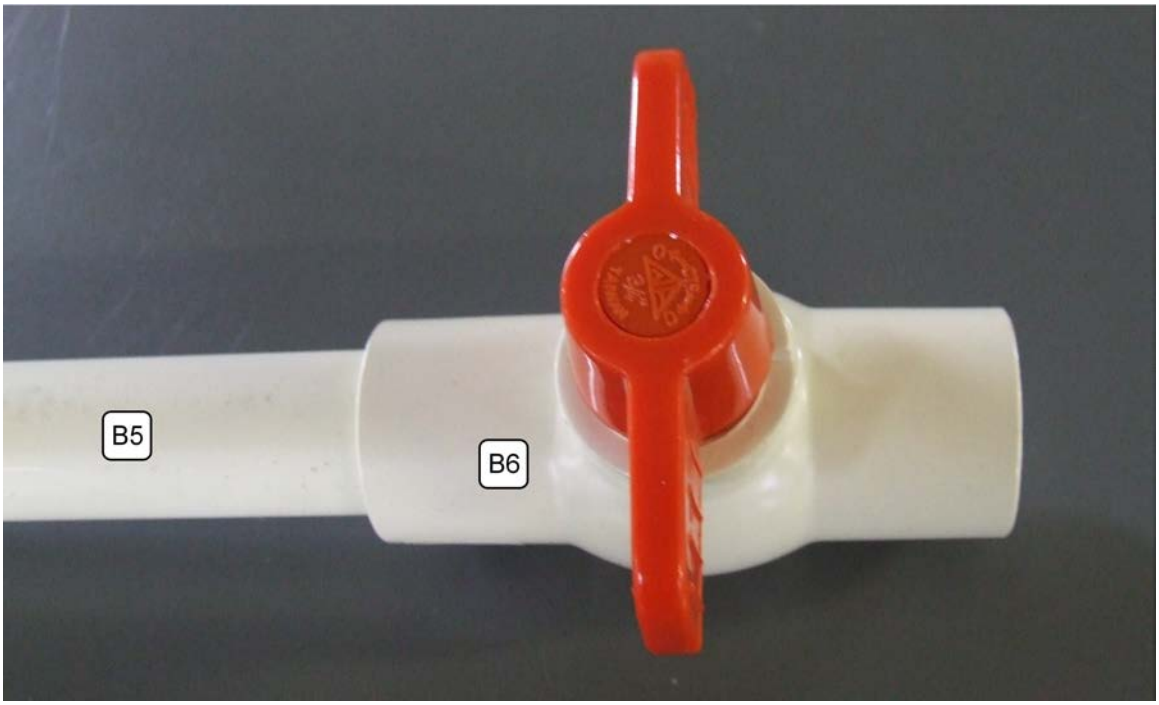

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Figure A-15 Section B, B5 and B6

The CPVC valve is a safety measure to be used to depressurize the launcher in the event of a misfire or for pressure testing the bottle clamp and release system.

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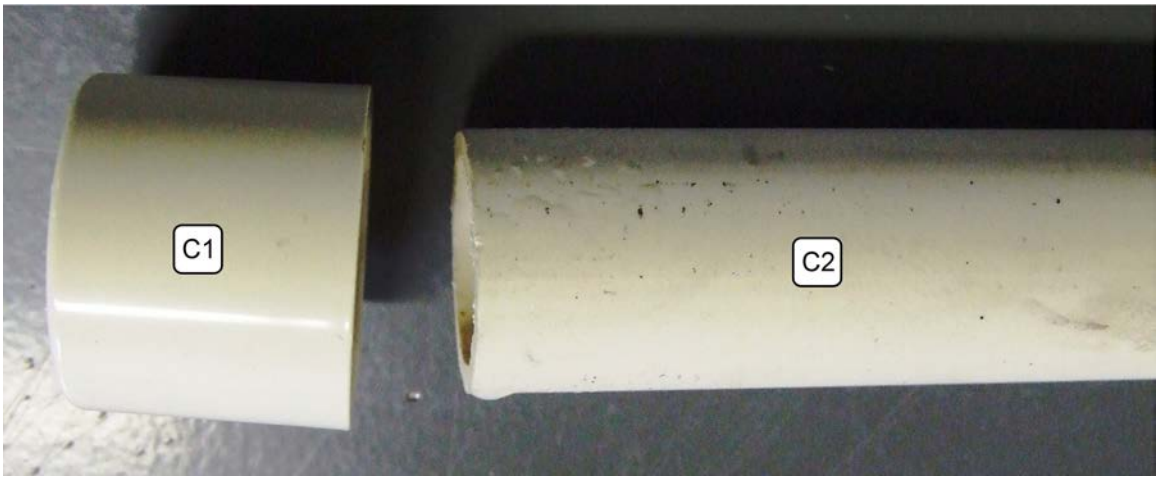
Section C

Apply CPVC Cement and join:

- C1 (¾-inch CPVC end cap) to C2 (24 inches of ¾-inch CPVC tube);



Note. Created by Director Cadets 3, 2011, Ottawa, ON: Department of National Defence.

Figure A-16 Section C, C1 and C2

- C2 (24 inches of ¾-inch CPVC tube) to C3 (¾-inch CPVC T-joint); and
- C3 (¾-inch CPVC T-joint) to C4 (7 inches of ¾-inch CPVC tube).

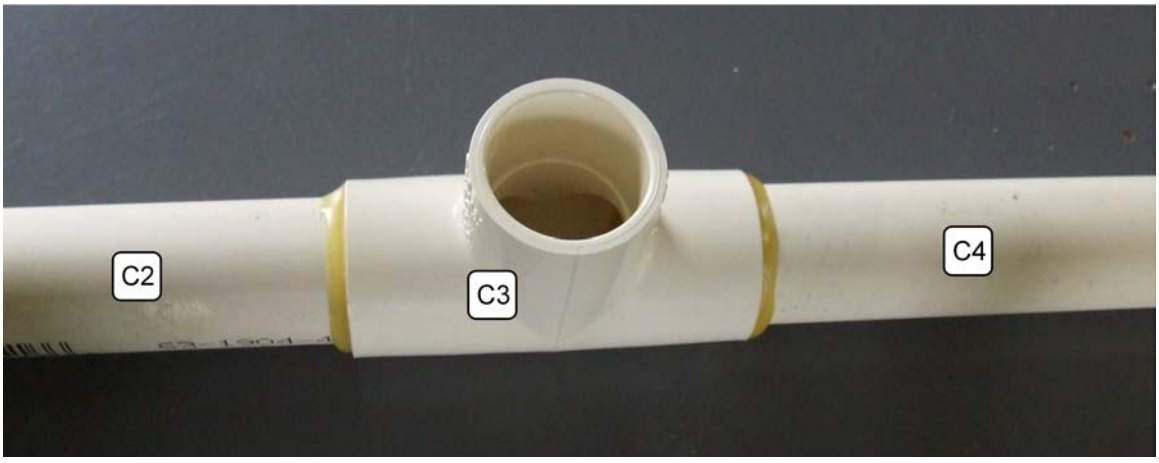


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Figure A-17 Section C, C2, C3 and C4

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Base Assembly

To build the base, apply CPVC Cement and join:

- A6 (3 inches of ¾-inch CPVC tube) of section A to C3 (¾-inch CPVC T-joint) of section C.
- B4 of section B to C4 of section C, make sure that section A is perpendicular to section B; and

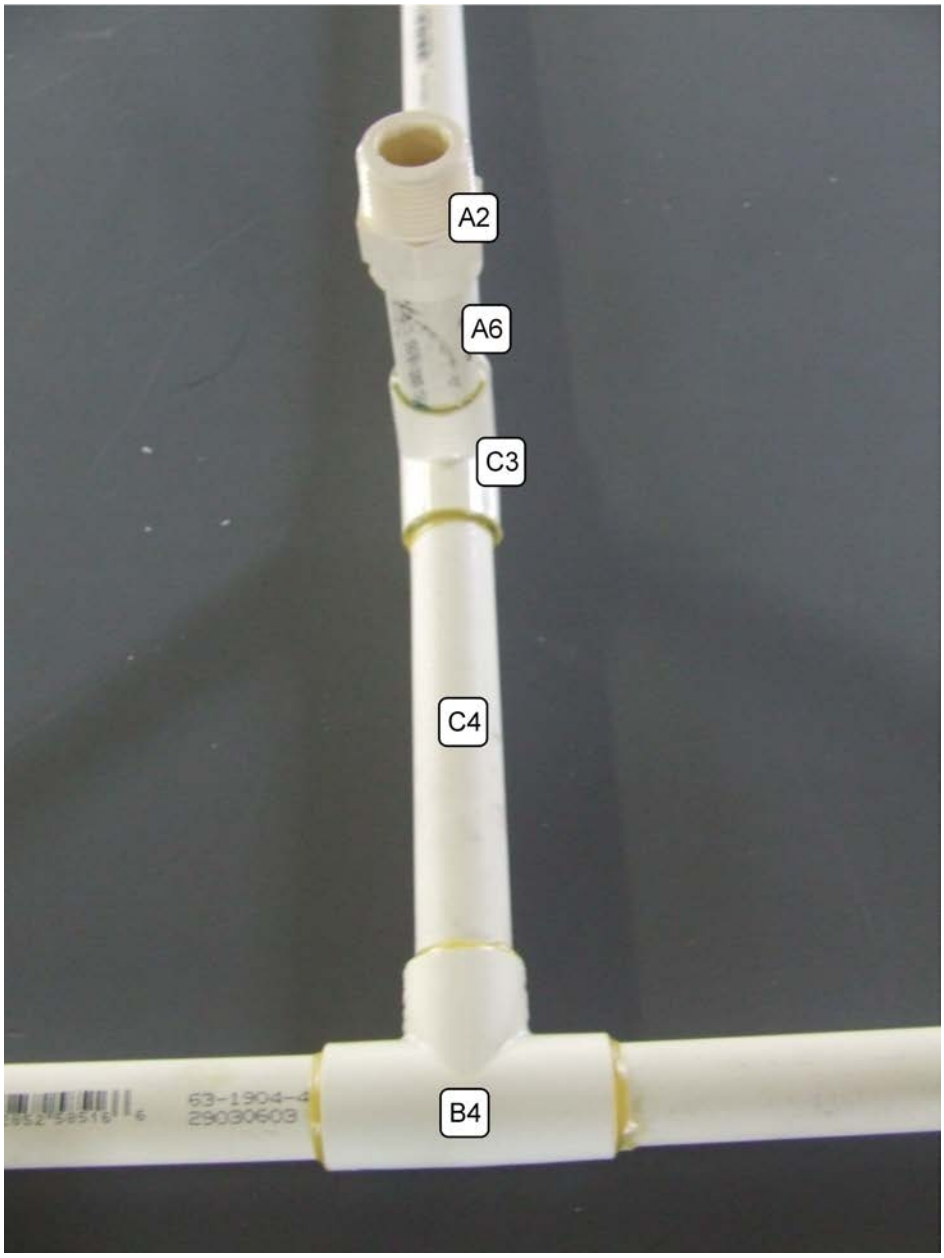

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Figure A-18 Sections A, B and C Joined Together

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To assemble the water rocket launcher, join section A with section B.



If during the glue process the parts fail to align properly because the glue has set too fast, cut off the misaligned part, purchase and glue a ¾ to ¾ CPVC coupler between the two parts and realign.

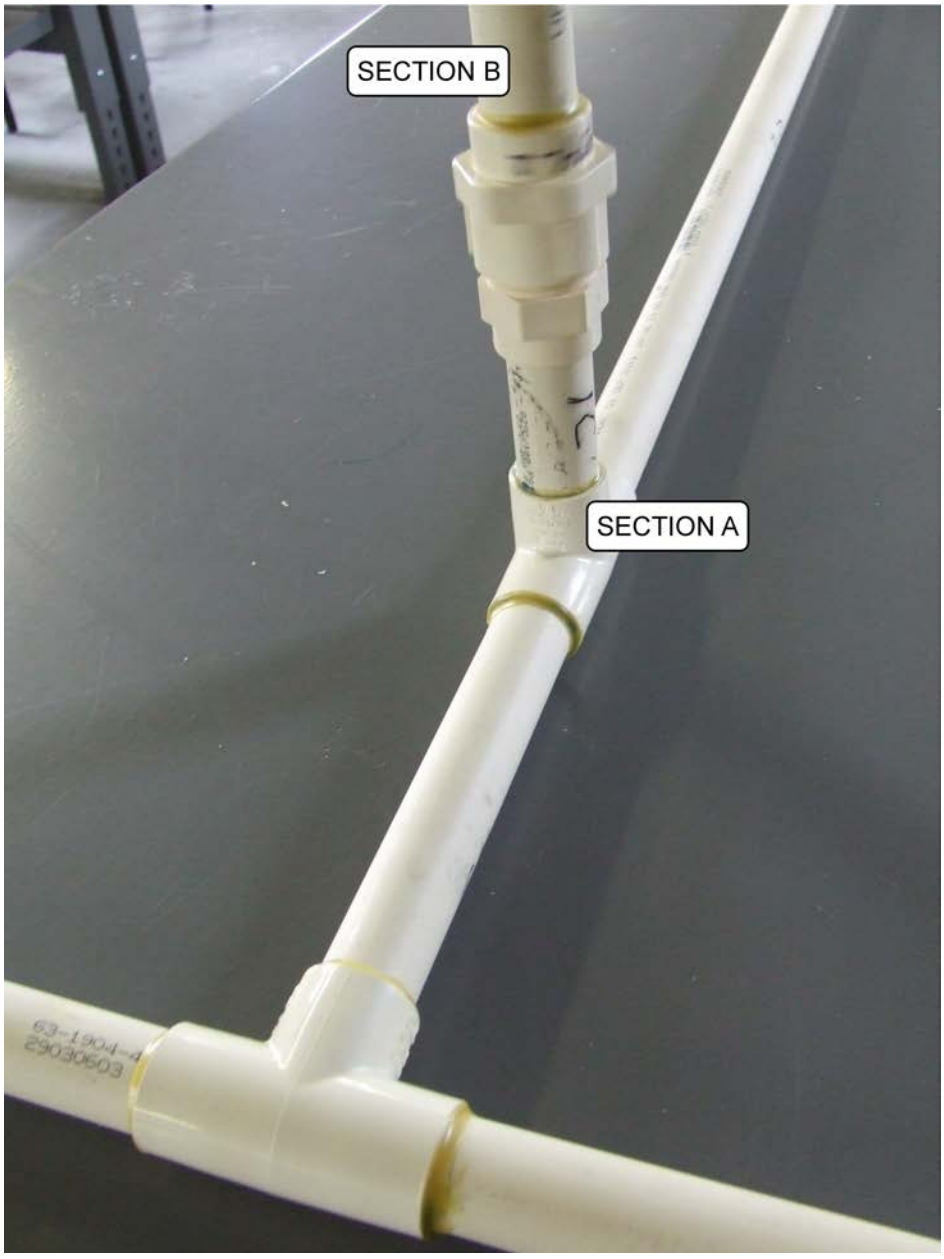

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Figure A-19 Section A joined with Section B.

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Bottle Clamp and Release System

To assemble the Bottle Clamp Release System

- Draw two parallel lines, six inches long on a piece of 8½" x 11" paper. Line A is one inch below the top edge of the paper and line B is three inches below line A. Use the corner of a second sheet of 8½ "x 11" paper as a square to mark a perpendicular line, line C, between lines A and B.

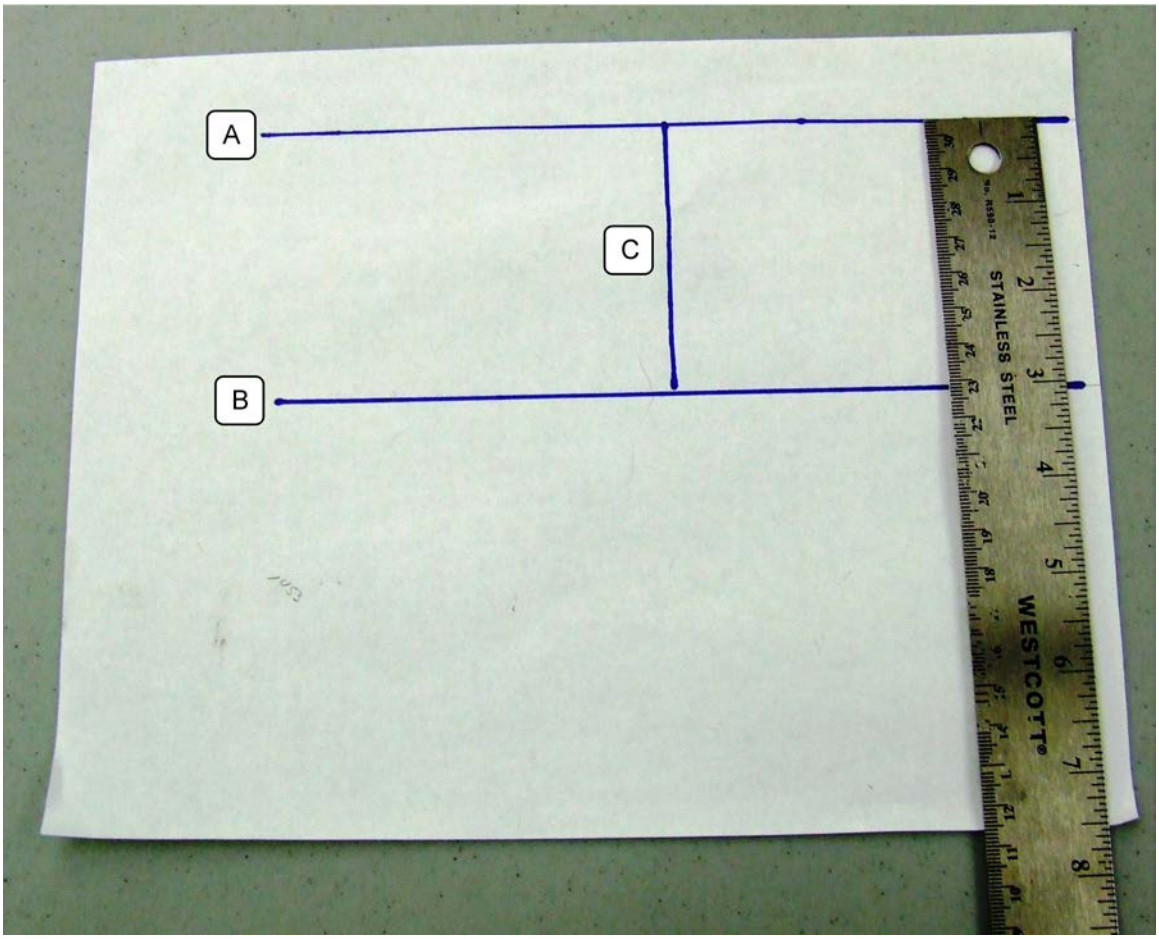

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Figure A-20 Laying Out the Cable Tie Position

- Lay the ruler along line A and lay the tape, sticky side up along line B. Ensure the ruler will not move off of line A by using tape or a weight. Place the ties across the tape with the head touching the ruler and

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check that the cable ties are perpendicular to lines A and B. Start at line C laying the cable ties 2 mm between each tie.

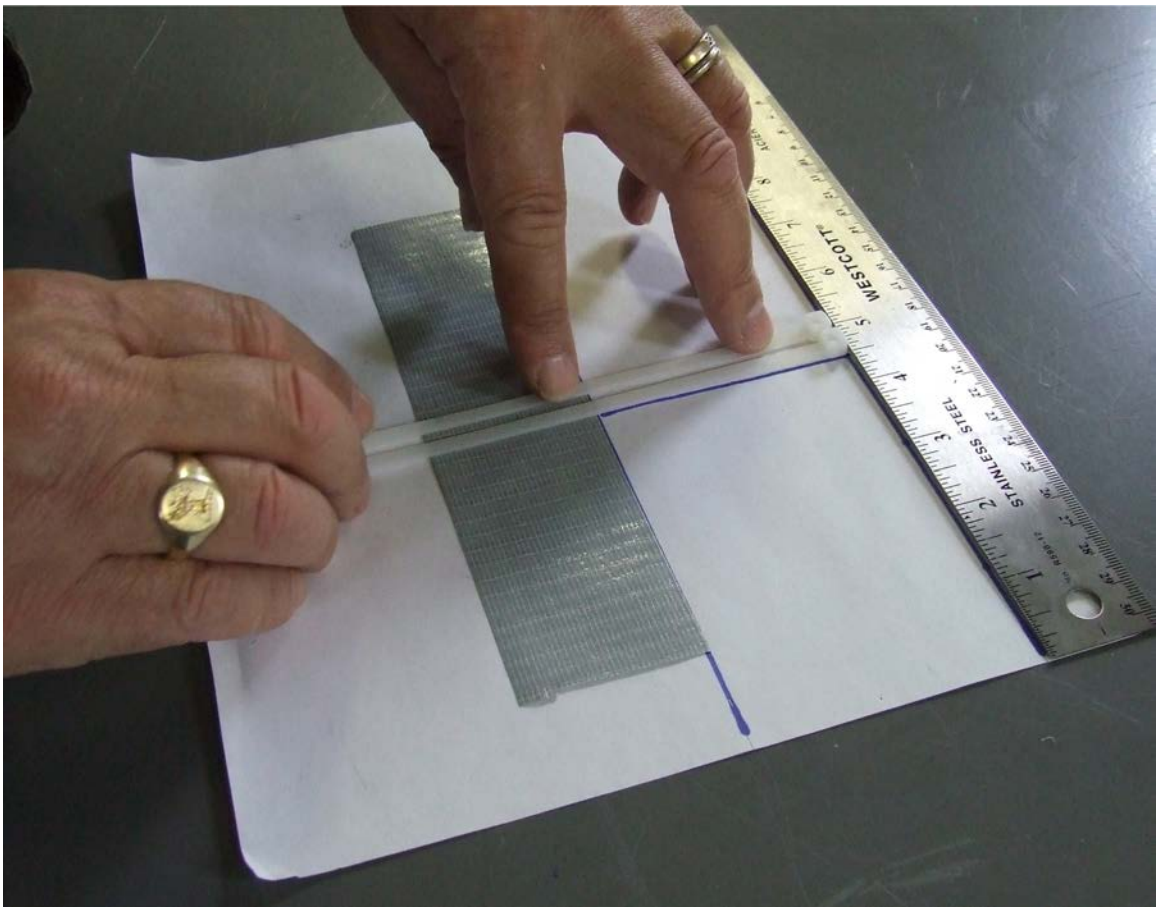

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Figure A-21 Placing the Cable Ties on the Duct Tape

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- Fold the tape ends over the exposed portion of the ties so that no adhesive is showing.

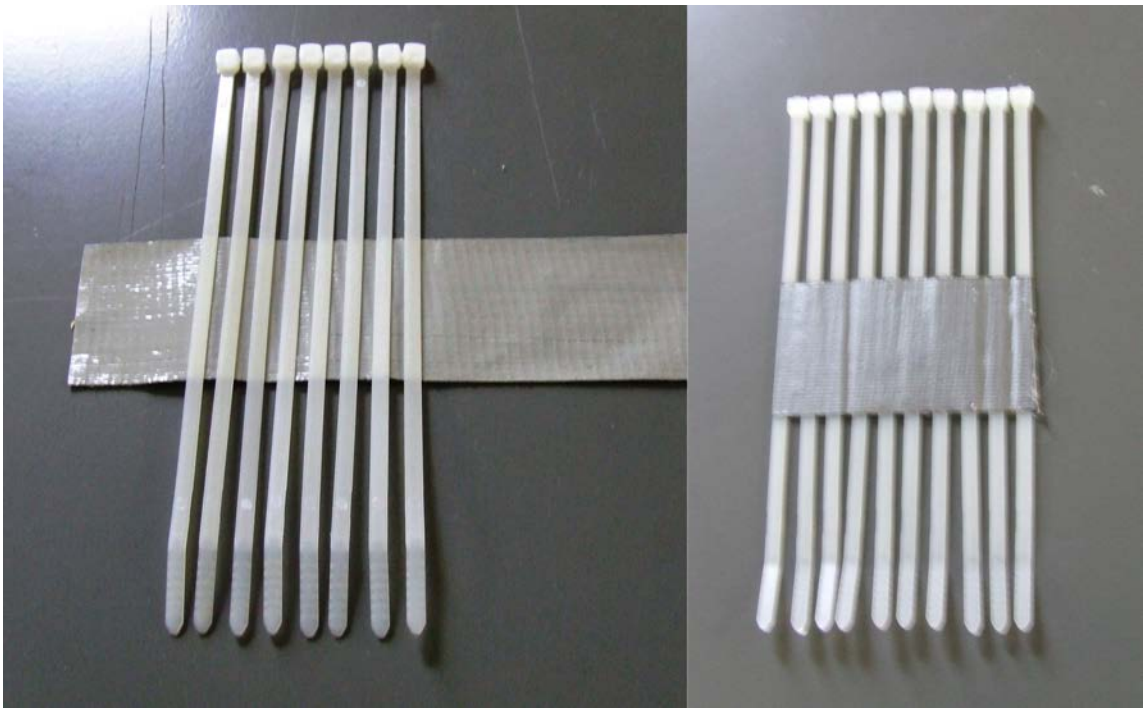

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Figure A-22 Cables Ties Adhered to the Duct Tape

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- Place the O-ring or hose washer over the ½-inch side of A2 (¾" x ½" coupler) until it rests on the shoulder of A2. The O-ring or hose washer may have to be stretched to fit onto the shoulder of A2.



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Figure A-23 Position of the O-Ring or Hose Washer on A2

- Place the 2 hose clamps on A (3¾-inch CPVC tube). Slide the bottle over the end of A1 (½-inch CPVC tube) and seat it against the O-ring or hose washer. Wrap the cable ties around the pipe so that the head of each cable tie faces inward and catches the lip of the bottle, holding the bottle tight to the O-ring or hose washer. Place the hose clamps over the cable ties and tape and tighten them so that the heads of

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the cable ties exert equal pressure around the ridge on the bottle. This makes an airtight seal between the bottle and the O-ring or hose washer.



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Figure A-24 Cable Ties Holding the Soda Bottle

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If the bottle leaks at the O-ring or hose washer, adjust the cable ties up or down on A3 (¾-inch CPVC tube) so the lip of the bottle is securely and evenly seated on the O-ring or hose washer. Lock the cable ties in this position by tightening the hose clamps around the duct tape.



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Figure A-25 Tie Cables Clamped to A3

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Bottle Release Mechanism

- Drill two 1/8-inch holes on opposite sides of the 1¼-inch ABS coupler.



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Figure A-26 Drilling 1/8-inch Holes in the ABS Coupler

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- Use scissors to cut the top and bottom off a 2-litre soda bottle. Use the centre section to make a plastic spring. Flatten the bottle section without creasing it and cut a 1¼ inch hole centered through both sides. Drill 1/8-inch holes on either side of the 1¼-inch holes through both sides.



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Figure A-27 Cutting the Hole in the Plastic Spring for Section A

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- Slide the plastic spring over the end of pipe A1 (½-inch CPVC tube), over the cable ties and up against the hose clamps.



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Figure A-28 Sliding the Spring over the Cable Ties

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- Slide the 1¼-inch ABS coupler over A1 (½-inch CPVC tube), over the cable ties and up against the plastic spring. Thread the braided string through the holes of the plastic spring and tie the ends to the holes drilled in the 1¼-inch ABS coupler.

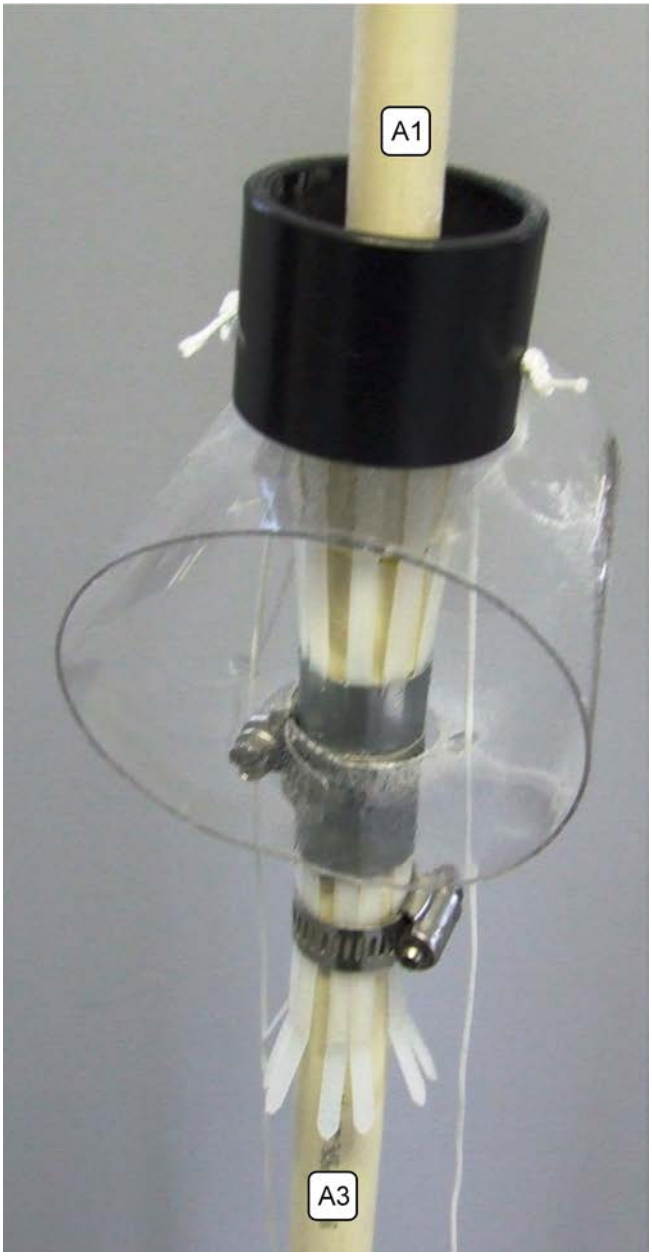

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Figure A-29 Couple Installed over Cable Ties and Against the Plastic Spring

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- Place a bottle in position on the launch tower. Pull the launch cords to lower the coupler and press the bottle neck onto the O-ring or hose washer. Then release the cord allowing the coupler to slide up, pressing the cable tie ends over the collar on the bottle, locking the bottle in place.

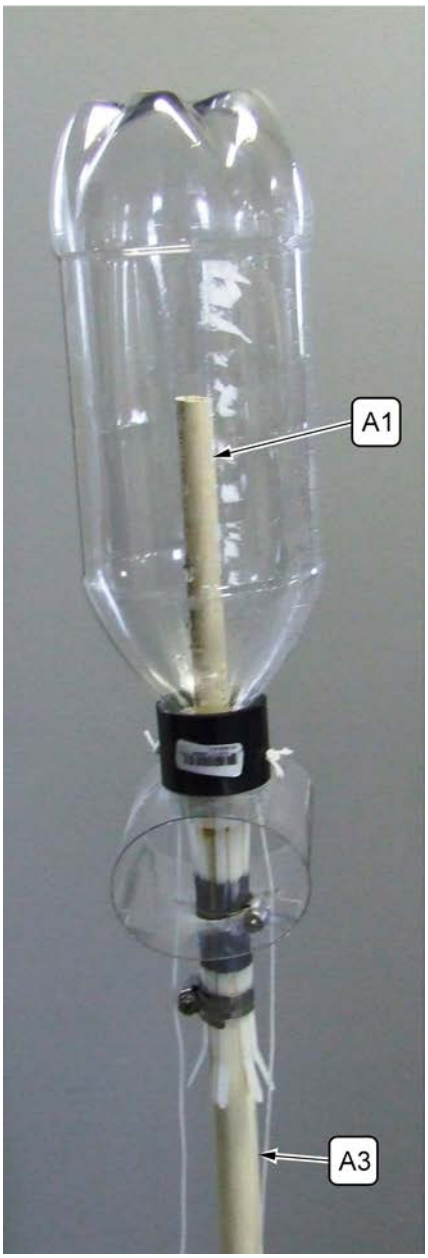

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Figure A-30 Soda Bottle Installed on Launch System

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Add a small amount of air pressure to test the bottle seal for leakage then depressurize the launcher. If air escapes around the lip of the bottle, gently rock the bottle on the tower. If the bottle continues to leak, the height of the cable ties on the upright A3 may need to be adjusted by loosening the clamps, and moving the cable ties up or down A3 to seal the bottle properly. The O-ring or hose washer should be compressed enough to seal the bottle to approximately 70 Psi.

- Test the release mechanism by pulling on the string to ensure the ABS coupler drops allowing the cable ties to open. When the string is released, the spring should push the coupler up and over the cable ties.

Launch Preparation

- Fill a bottle 1/3 full with water.



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Figure A-31 Loading the Soda Bottle onto the Launch System

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- Lay the launcher on its side and slide the bottle onto the end of the A1 (½-inch CPVC tube). Pull down on the trigger so that the bottle can seal against the O-ring or hose washer and the cable ties catch the lip of the bottle. Release the string and let the coupler slide back over the cable ties to hold the bottle in place. Sit the launcher upright and adjust the bottle to stop any leaking.



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Figure A-32 Soda Bottle Ready for Launch



Place a weighted object (sand bag) on the launcher to hold it in an upright position.

- Run the launch cord under the tubing of the launcher so that when pulled, the cord pulls downwards on the collar of the launch tower.

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- Attach the selected method for inflating air into the bottle to part B1 (tire valve stem). Method for inflating up to 70 Psi of air can include:
    - a foot air pump,
    - a bicycle air pump, or
    - a compressor.

Do not exceed 70 Psi.



When inflating air into the bottle launcher, the faster the air is added, the less amount of water leakage.

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Figure A-33 Assembled Water Rocket Launch System

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LAUNCH SITE SET-UP

1. Have the cadets participate in a safety briefing before the launch site is set up, covering the following points:

- All launch systems will be placed in “safe” mode between each flight.
- When a rocket is descending out of control, launch site personnel will point at the rocket and repeat the phrase “heads up” until the rocket has landed.
- No horseplay will be tolerated.
- A safe rendezvous point will be clearly indicated. In the event of an emergency, launch site staff will move all cadets and staff to this point.
- The area required for launching model rockets should be at least 10 m by 20 m. The spectators should be located in an area at least 20 m from the launch tower. Bleachers at a baseball field or soccer field are suitable.
- The rocket can reach a height of 60 m (200 feet) at apogee and can be flown safely from the suggested field size.

2. Set up rocket launch site as per Figure 5A-1. Wind direction should be accounted for by placing the tower closer to the windward side of the field.

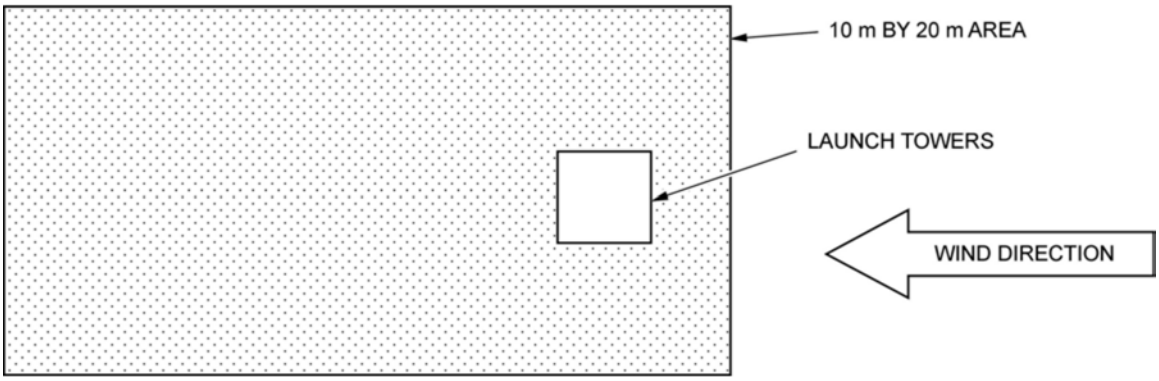

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Figure B-1 Layout for a Water Rocket Launch Site

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WATER ROCKET SAFETY ORDERS

1. **Definitions.** For the purposes of this safety order, a 'Water Rocket' is defined as any rocket whose thrust is generated by expansion of a compressed air. An inert fluid such as water is used for thrust augmentation. A soda bottle refers to a Polyethylene Terephthalate (PET) soda bottle between 500 ml and 2 l.

2. **Scope.** This order applies to water rockets used in cadet activities having a pressure chamber volume greater than 500 ml or a launch pressure exceeding 35 psi.

3. **Materials.** The pressure chamber of the rocket shall be a PET plastic soda bottle between 500ml and 2l. Only lightweight, non-metal parts shall be used for the nose, body, and fins.

4. **Compressed Gas Safety.** A safe distance shall be maintained at all times between persons and pressurized water rockets or launchers. The recommended safe distance is as follows:

Launch Pressure	With Eye Protection	Without Eye Protection
Up to 60 psi	10'	20'
Above 60 psi	20'	40'

5. **Pressurization System.** A small portable compressor, 12 volt tire inflator or bicycle pump is used to pressurize the launch system. The pressure shall not exceed 70 pounds per square inch.

6. **Launcher.** The launcher shall hold the rocket to within 30 degrees of vertical to ensure that it flies nearly straight up. It shall provide a stable support platform against wind and any triggering forces, and allow the rocket to be pressurized and depressurized from a safe distance. Launchers shall be constructed from materials rated for at least 3 times the intended launch pressure.

7. **Launch Safety.** A countdown prior to launch ensures that spectators are paying attention and are a safe distance away. If the rocket does not launch when triggered, all persons shall stay at a safe distance from the launch tower until it has been depressurized by launch staff.

8. **Size and Weight.** A water rocket whose mass (excluding water) exceeds 454 grams (1 lb) shall be considered a "Large Model Rocket" for the purpose of compliance with Federal Aviation Administration regulations. Rockets used in cadet activities shall exceed 454 grams (1 lb), or be longer than the length of two soda bottles.

9. **Flight Safety.** Water rockets shall not be directed at targets, into clouds, or near airplanes or other vehicles. Water rocket payloads shall not include flammable, explosive, dangerous (metal, rock, or other potentially hazardous objects) or live vertebrae.

10. **Launch Site.** Water rockets shall be launched outdoors, in an open area at least 100 feet on a side (for rockets with using a launch pressure of 60 psi or less), or 500 feet on a side (for rockets using higher pressure).

11. **Recovery System.** A recovery system such as a streamer, parachute, or tumble recovery can be used for rockets launched with over 60 psi, with the intent to return it safely to earth without damage.

12. **Recovery Safety.** Recovery shall not be attempted from power lines, tall trees, or other dangerous places.

13. **Load Fraction.** Water rockets shall be launched with a load fraction not exceeding .33. Load Fraction is the ratio of the water volume to the total volume of the motor. For example, 0.66 litres of water in a 2-liter soda bottle, one third full, the load fraction is 0.33.

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