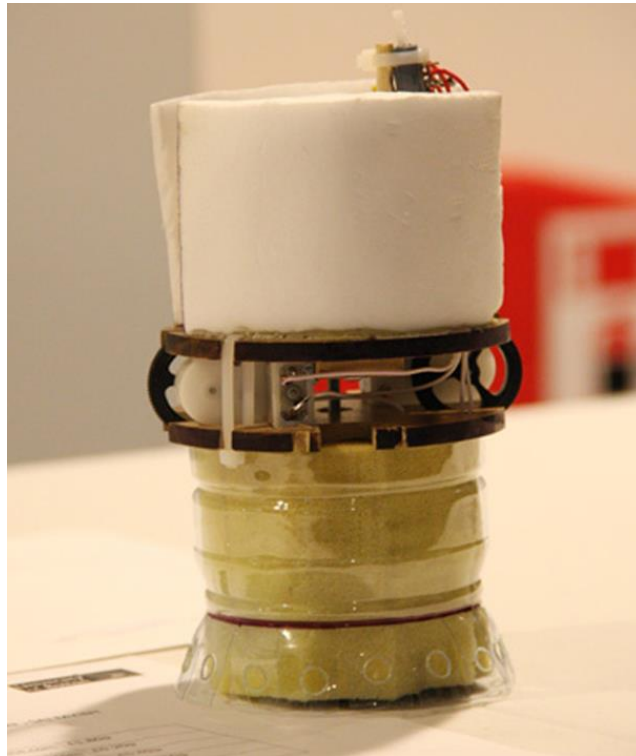


2nd YEAR DESIGN CHALLENGE PROJECT SPECIFICATION AND RULES 2023

Institution of
**MECHANICAL
ENGINEERS**

IMechE 2nd YEAR DESIGN CHALLENGE

INTERNAL PIPE CLIMBER



Project Specification for the 2023 Internal Pipe Climber 2nd Year Undergraduate Design Challenge

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Note: this specification must be read in conjunction with the document "IMechE 1st & 2nd Year Design Challenge - General Specification 2023" available on the [IMechE Design Challenge website](#).

Please check the IMechE Design Challenge website for updates.

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List of Amendments

Version	Page	Details	Date
0.1 DRAFT	-	Draft Release – not for circulation beyond the committee	05-11-2022

Please report any errors to Emma.Pateman@imeche.org so that corrections can be made.

List of Major Changes Since 2018

- Scoring is now based on the fastest time with a bonus score for hitting the target. Devices must hit the target area to register a time score
- The challenge is now one and a half cycles, reduced from two and a half
- There are three Start Lines at different height to add some variability to the challenge. The Datum Line acts as Start Line 1
- The chain is now 0.106 kg/m

1. Introduction

The Design Challenge, organised by the Institution of Mechanical Engineers, is an annual competition for students in their second year of study on an undergraduate engineering degree programme. The Challenge comprises five parts, all of which are detailed in the General Specification.



This year the challenge is to design, build and test a device to simulate pipeline pigging. Such a device, known as a 'pig', is used to perform various cleaning, clearing, maintenance, inspection, dimensioning, process and pipeline testing operations on new and existing pipelines.

Figure 1: A Pipeline Pig

The challenge is to design, build and test a device to climb up the inside of a piece of vertical transparent pipe, lifting an increasing load. The 'device' can be of any construction and propulsion method, limited only by cost, and size, within the specification detailed below. The competition encourages the use of sensors and control systems, to operate a device, which must:

- be capable of lifting an increasing load
- complete one and a half cycles travelling up and down the tube
- stop accurately at the mid-point on the second climb
- be started manually, but once it has done so, no interference or outside control is allowed

The increasing load will be in the form of a chain, where the weight of chain to be lifted is specified as 0.106 kg/m.

The relative performance will be determined by the speed and accuracy of the device.

In the spirit of the competition, it is expected that the device be designed, developed and manufactured by students within the facilities of their university. Any member of the team should have a good understanding of the design principles, theories, manufacturing methods and materials used.

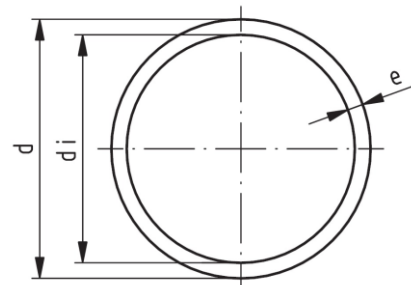
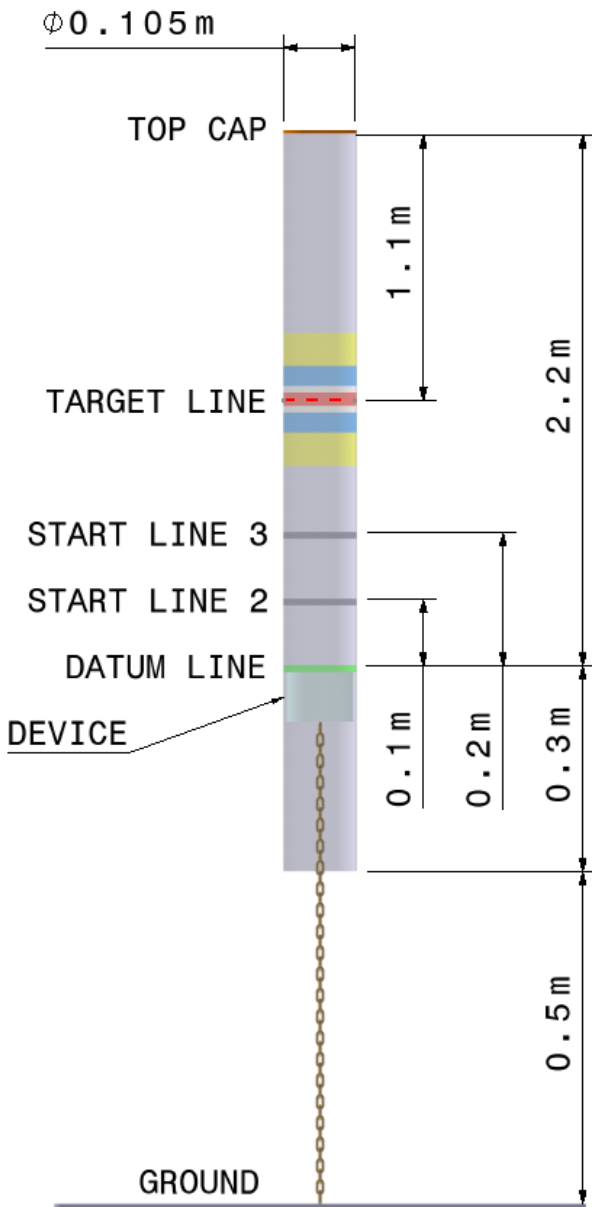
Note: this specification must be read in conjunction with the document "IMechE 2nd & 2nd Year Design Challenge – General Specification 2023" available on the [IMechE Design Challenge website](#).

2. Competition Conditions

The test area will consist of up to four identical pipes to allow for parallel runs between teams. Each pipe is made from transparent PVC-U, has an internal diameter of 0.105m and is 2.5m long. The 'Device Controller' is allowed to hold their device in position up to or below the Start Line (min. 0.3m above bottom of pipe) before starting.

To add some variability to the challenge, there will be three Start Lines, 0.1m apart, as shown in Figure 2. The Datum Line also acts as Start Line 1.

The teams competing in a heat will be required to start their devices simultaneously. Once started there can be no outside interference. Having started their device, the Device Controller must then step away from the pipe. The pipes will be vertical, noting that surfaces will be uniform within normal production tolerances.



Outside Diameter	d	110.0 mm
Wall Thickness	e	2.2 mm
Inside Diameter	di	105.6 mm

Figure 3: Pipe Dimensions

Figure 2: The Internal Pipe Climber and Test Rig

The one and a half cycles will consist of three phases, as shown in Figure 4 below:

- Phase 1: From the designated Start Line
All the way up to the top, with no requirement to stop at the target
- Phase 2: Reverse and return from the top and travel down the pipe
All the way down, with no requirement to stop at the target
The device must pass below the Datum Line before reversing
- Phase 3: From below the Datum Line
Up, and stop at the target to complete the challenge

Details about the heats and running order will be presented later in this document, but note that there will be a different Start Line for each heat. In Figure 2, the Datum Line also acts as Start Line 1.

Whichever Start Line is used, the device must return below the Datum Line during Phase 2 of the run.

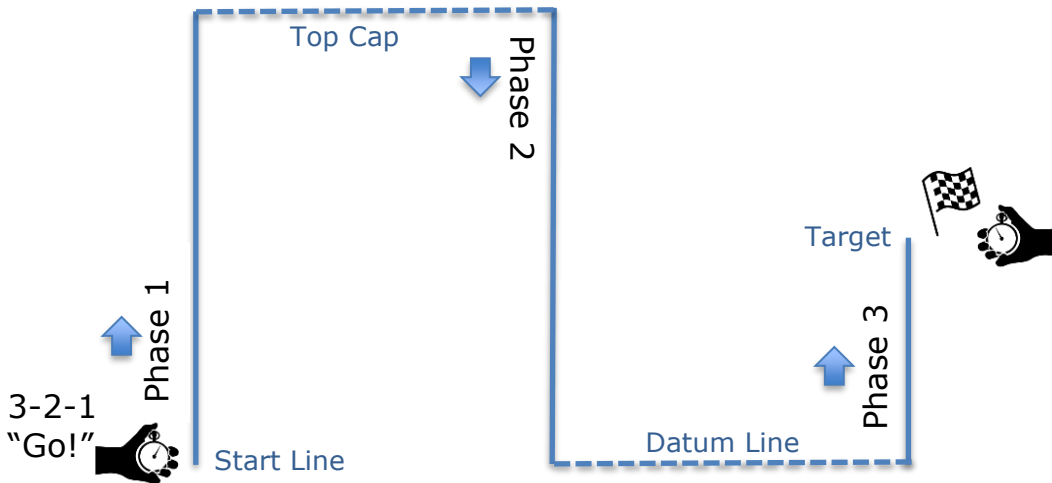


Figure 4: The Three Phases of the Internal Pipe Climbing Challenge.

3. Technical Regulations for the Internal Pipe Climber

- 3.1 The device can be of any type, but it must be totally self-contained, and at all times during the competition fit within a pipe internal diameter of 0.105m and length 0.3m. On the day of the competition this will be checked using a gauge.
- 3.2 The pipe will be 2.5m long. According to the manufacturer's specification, the outside diameter is 110.0mm and the wall thickness is 2.2mm, giving an internal diameter of 105.6mm. Further details, including where to download a CAD model of a section of pipe, are included in Appendix 1.
- 3.3 The device may use any form of propulsion available within the cost limit. Propulsion systems may not include explosives or combustion.
- 3.4 Controlling devices, whether by discrete components, or devices such as an Arduino, should be mounted on the device and kept within the specified volume at all times.
- 3.5 No proprietary, pre-programmed control units may be used. This rule means devices such as Arduinos can be used, but the team must write their own, original control software and not use controllers with pre-installed code.
- 3.6 Teams are not allowed to use ready-made code or routines that have been downloaded from an online resource.
- 3.7 Parts from existing devices (i.e. entire wheel and motor assemblies) are not permitted.
- 3.8 The chain will be 2.5m long, with a weight of 0.265kg for the 2.5m length (0.106kg/m). The link thickness is 2.5mm. The chain is not part of the operational envelope. Further details are included in Appendix 1.
- 3.9 Each device must have a quick and simple method of attaching and detaching the chain, which should not require the use of tools. It is up to individual teams as to how this is achieved, but any coupling must not cause the device to violate the control volume dimensions.
- 3.10 Failure of the attachment or loss of the chain will result in disqualification from that heat.
- 3.11 The target area will be marked using a sticker or transfer as shown in Appendix 2. The datum line and start lines will be marked with tape. The exact colour and opacity of tape, stickers or transfers cannot be guaranteed.
- 3.12 For starting and scoring, the position of the device relative to the mid-point target and start/datum line will be determined relative to the upper surface of a datum disc, which forms the top surface of the device. The datum disc must be a flat, round disc of at least 90mm diameter and no less than 3mm thick.

- 3.13 Only switches and sensors used for controlling the device may protrude above the datum disc. They must be kept within the specified volume and be below the datum line at the start.
- 3.14 Devices must be started remotely via a low voltage, wired, electrical switch. For convenience, when starting, this can be on a short lead that dangles out of the bottom of the pipe.
- 3.15 The start switch and its wiring is the only component that is excluded from the operational envelope.
- 3.16 Team members must not tamper with the inner surface of the pipe. No substances, such as adhesives or lubricants, can be used between the device and the pipe. Devices must not cause any damage or leave any debris on the internal surfaces of the pipe.
- 3.17 Devices must be regarded as safe and reasonable and conform with the General Specification as judged by the member of staff responsible for the team. Consideration should be given to guarding if there is risk of entanglement or entrapment.

4. Competition Rules for the Internal Pipe Climber

- 4.1 All devices must be available for scrutineering prior to commencement of the competition.
- 4.2 No practice runs in the pipes are permitted, but devices may be tested away from the pipes for all other functionality.
- 4.3 Teams will compete head to head in qualifying for a place in the final. The relative performance will be determined by the time taken to complete a run plus a bonus score for hitting the target.
- 4.4 During qualifying every team will attempt three runs, each run being in a different pipe.
- 4.5 Qualifying runs will consist of up to four teams running in parallel.
- 4.6 The time and bonus score will be recorded for each successful attempt.
- 4.7 The time is measured from the "Starters Order" until the device stops in the target area at the end of the run.
- 4.8 The device must contact the top cap after the upward travel and before the downward travel.
- 4.9 The device must pass below the Datum Line before reversing.
- 4.10 Each team's highest score (time plus bonus) from qualifying will determine the overall leaderboard.

- 4.11 Teams must attempt all three runs in qualifying to have their quickest time recorded.
- 4.12 The top four teams in qualifying returning the quickest times will progress to the final.
- 4.13 In the event of a tie at the end of qualifying, or in the final, there will be a re-run of one single attempt. If there is a further tie, the lightest device will be the winner.
- 4.14 In the unlikely event of there being a technical fault with the test apparatus (not devices) deemed to unfairly disadvantage a team, there will be a rerun.
- 4.15 The time limit for a run will be 2 minutes. Time will start from the end of the timekeepers starting countdown.
- 4.16 Participating teams will have a minimum of 1 minute before a run to prepare their device in the pipe.
- 4.17 Teams not ready within the allotted time before a run will forfeit that attempt.
- 4.18 Each team must appoint a 'Device Controller' who will be the only person to attend to the device during a run.
- 4.19 Device Controllers must step back from the pipe, immediately after starting their device, on a count of 3, 2, 1, GO!
- 4.20 Once a run has started the device may not be touched until it is over.
- 4.21 If a device is started before the starters order it will forfeit that attempt.
- 4.22 During a run, all other team members must be outside the test area.
- 4.23 A judge will be allocated to each test area to ensure the correct procedure is followed.
- 4.24 Repairs and minor alterations are allowed to the device between each attempt within a 1 minute time limit.
- 4.25 It is permissible to replenish the device's energy source between the heat and final but not during individual runs during a heat or the final. This means that the energy source can be replenished once during the competition.
- 4.26 If a device does not meet these requirements, and modification cannot be made within the allocated time period to allow it to comply, then it will be deemed withdrawn from this part of the competition.
- 4.27 A camera (smartphone) will continuously film the activity in the competition so that if there is a dispute it can easily be resolved.
- 4.28 Breach of any rule during competition will forfeit that heat or final.

- 4.29 Continued breaches or behaviour unbecoming of the spirit of the challenge will result in the team being disqualified from the competition.
- 4.30 Any queries about the equipment during the competition must be raised with the head judge. Only the team leader is allowed to approach the official and the team must abide by any decision made.

5. Run Procedure for the Internal Pipe Climber

- 5.1 Clear instruction on the running order for the heats and finals will be given at the event.
- 5.2 All teams must display an A4 sheet detailing the teams name and University when competing. The name sheets will be supplied by the competition host.
- 5.3 The device must be loaded into the pipe during the one minute preparation time. The chain must be attached during this period.
- 5.4 The Device Controller is allowed to hold their device in position up to, or below, the datum or start line before starting.
- 5.5 Device Controllers will raise their hand clearly to show readiness within the one minute period. If all the teams are ready, an attempt can commence.
- 5.6 Once ready, teams will be instructed to "Prepare to Start" and then on a count of 3,2,1, GO! each team will start their device. The timer will start on Go.
- 5.7 The device cannot be touched until the judge signifies that an attempt is complete.
- 5.8 Once all devices have stopped, the judges will record the run times and scores.
- 5.9 The run procedure should be configured by the organisers such that one team does not run in the same pipe twice during a heat or the final.

6. Scoring for the Internal Pipe Climber Competition

- 6.1 Scores are made up of two elements. Firstly, up to 20 points for the fastest device. Secondly, up to 10 bonus points for hitting the target (see 6.6).
- 6.2 The fastest team in the heats or final will be awarded 20 points.
- 6.3 The slowest team in the heats or final will be awarded 10 points.
- 6.4 Other teams will be awarded points on a linear pro rata basis, rounded down. Example scores are shown in Appendix 3.
- 6.5 Points are only awarded for a successful run where a device hits the target area. If a team fails to hit the target it will receive zero bonus points and zero time points.
- 6.6 Bonus points will be awarded for devices that stop accurately on the mid-point target as follows:
- within ± 10 mm will score 10 points
 - within ± 20 mm will score 8 points
 - within ± 50 mm will score 4 points
 - within ± 100 mm will score 2 points
- The scoring zones are shown in Appendix 2.
- 6.7 If the device comes to rest in the target area, such that the datum disc is at an angle breaking two scoring zones, then the higher score will be recorded.
- 6.8 Teams failing to finish a run will be awarded zero points.

Regional Finals

In the Regional Finals, individual awards are made for each section of the competition.

- 6.9 For the Regional Finals, the winner of The Challenge in each region will qualify for the National Finals.

National Final



In the National Final, points are accumulated for each section of the competition.

- 6.10 The maximum score available in the heats or final is 30 points, as detailed in 6.2 to 6.8 above.
- 6.11 Scores from the heats will be carried forward to the final. 30 points will be available in the final, meaning a total of 60 points is possible for the pipe climber competition.

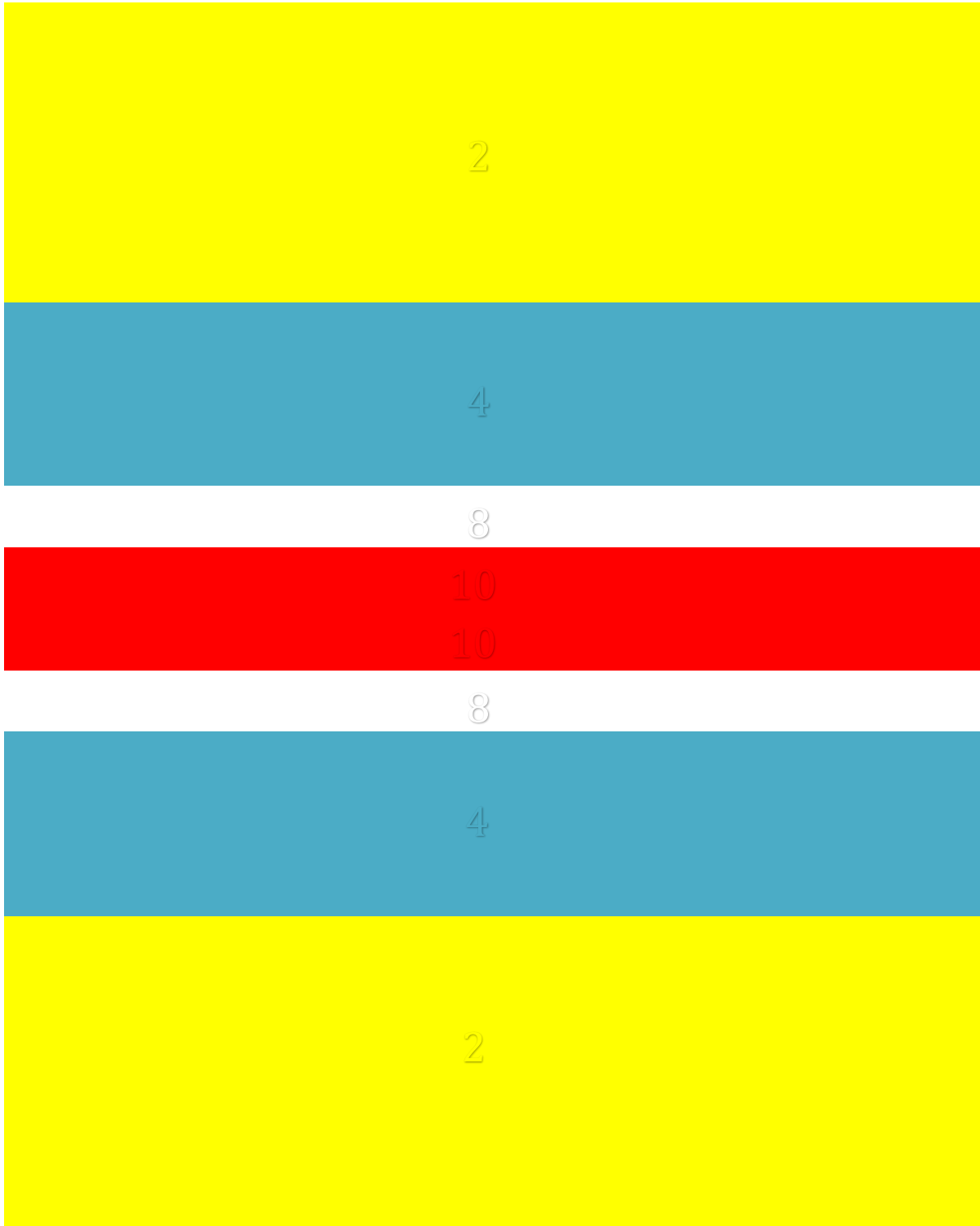
Appendix 1 – Equipment List and Suppliers

All prices approximate and correct at time of publishing.

Links are provided for ease of reference only, these are not nominated suppliers.

	<p>Pipe: 2.5m long, outside diameter 110.0mm, wall thickness 2.2mm, internal diameter 105.6mm. Possible supplier GF Piping Systems Search for project code 192017039 Link to GFPS website (for reference only) Note to teams: you can download a CAD model of a sample section of pipe from this website.</p> <p>Note to university supervisors: you will need to shop around to get the best price for the pipe. Pay particular attention to the wall thickness and inside diameter before ordering to avoid ending up with a smaller inside diameter than specified.</p>	<p>£225 inc. VAT for 2.5m</p>
	<p>Chain: 2.5m long, weight of 0.265kg for the 2.5m length (0.106kg/m). Link thickness is 2.5mm. Possible supplier B & Q Search for product code 1520639 Link to B&Q website (for reference only)</p>	<p>£8.10 inc. VAT</p>

Appendix 2 – Target



The Scoring Zones Around the Mid-Point Target (Scale 1:1).

If printed 1:1, this page can be used to create transfers for sticking on the tube.

Appendix 3 – Challenge Scoring Examples

Recorded Run Time	Calculated Score	Rounded Score
01:22	14.34	14
00:37	19.76	19
01:58	10.00	10
00:35	20.00	20
01:02	16.75	16
01:00	16.99	16

20 points for the quickest time

10 points for the slowest time

Only successful attempts, where devices hit the target, are eligible for time points

Total score = time score + bonus score
30 max. 20 max. 10 max.