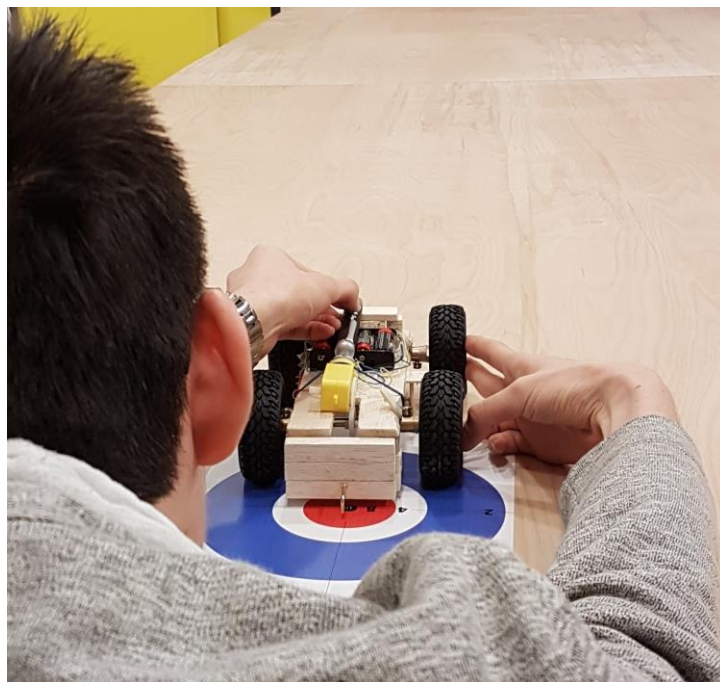


Institution of
**MECHANICAL
ENGINEERS**

DESIGN CHALLENGE 2nd YEAR PROJECT SPECIFICATION AND RULES 2021

IMechE 2nd YEAR DESIGN CHALLENGE

REPEATABLE VEHICLE



Project Specification for the 2021 Repeatable Vehicle 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 2021” available on the IMechE Design Challenge website.

Please check the supplementary document

**“IMechE 1st & 2nd Year Design Challenge - COVID-19
Amendments 2021”**

**for any special arrangements for this year’s competition,
available on the**

IMechE Design Challenge website.

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List of Amendments:

Version	Page	Details	Date
1.0	-	Full Release (no changes from DRAFT V0.1)	28-10-2020

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 later in this specification.

This year, the competition is to build a repeatable vehicle. The 'vehicle can be any movable device - wheeled, walking, sliding, jumping, rolling or other. The vehicle runs in a 'lane' with a wall at one end and two circular targets marked on the floor.

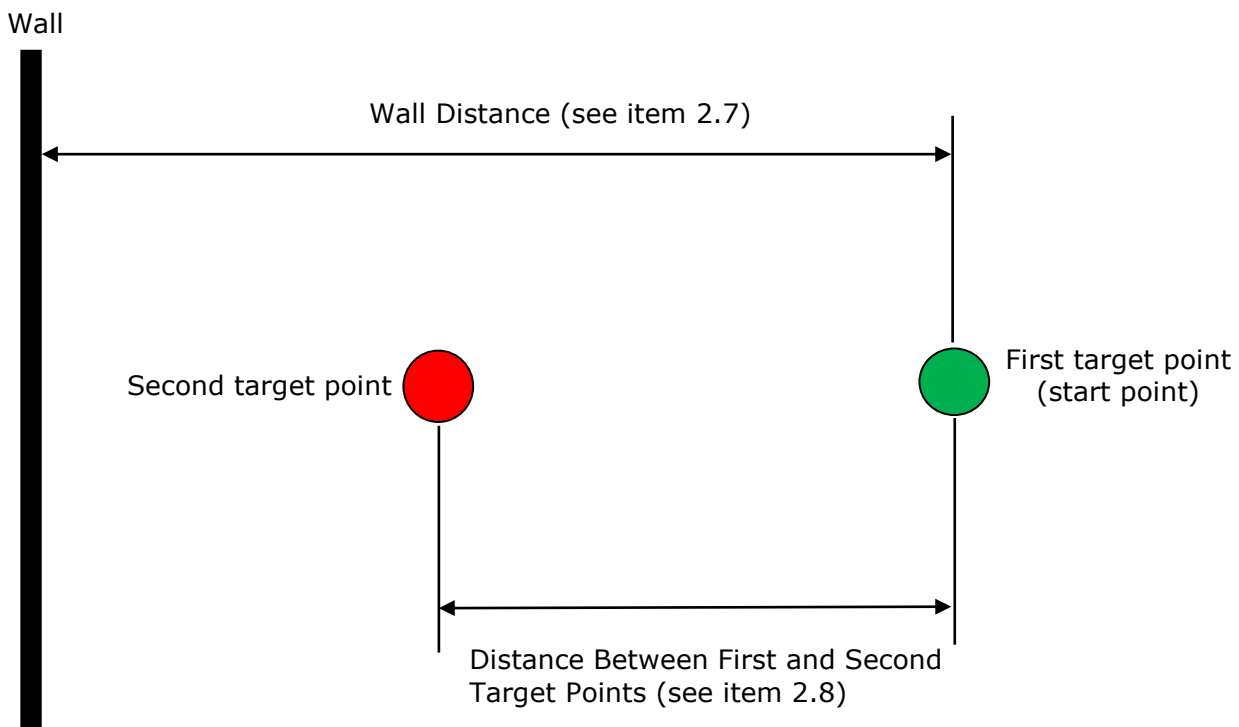


Figure 1. Schematic of the target points relative to the wall (not to scale).

The device starts at an origin on the target furthest from the wall and must complete two distinct phases for the challenge. First, the vehicle must move from its start point to touch the wall placed at right angles to the lane and then return to stop as close as possible to the start point. Here it must pause for between 5 and 10 seconds, before starting a second phase, heading once again in the direction of the wall. This time, before reaching the wall, the vehicle must find a second target, and stop accurately on its centre. The vehicle is to be started manually, but once it has done so, no interference or outside control is allowed, including the time it pauses for a few seconds between phases one and two.

Schematically (in stages) what needs to be done is shown in Figures 2 and 3. The aim of the competition is to make a device stop with 'd1' and 'd2' as small as possible, as shown in Figures 2 and 3.

Wall

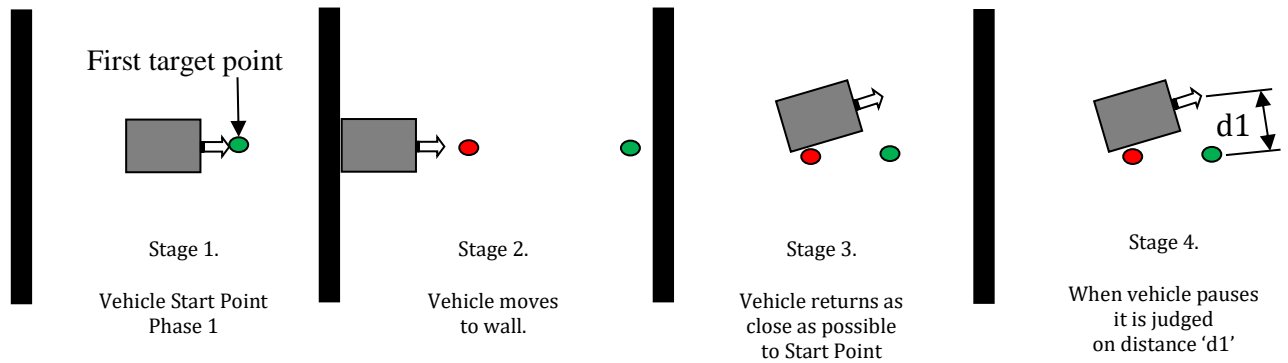


Figure 2. Schematic of the first phase shown in four stages (not to scale; 'vehicle' does not have to be as shown).

Wall

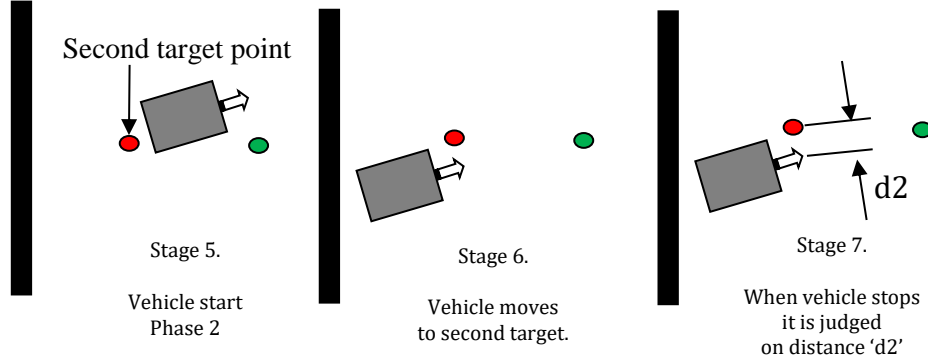


Figure 3. Schematic of the second phase shown in three stages.

The device can be of any construction and propulsion method, limited only by cost, and size, within the specification detailed below. However, the device must be totally self-contained and must have no other means of external control, except for a start switch. Full details are given later.

Points will be awarded for the accuracy of the device based on its ability to return to the original starting position on the target.

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 1st & 2nd Year Design Challenge – General Specification 2021" available on the IMechE Design Challenge website.

2. Main Competition Conditions

Devices run on a 1m wide lane over a range of distance from 1.4m – 4.0m. The lane will be horizontal and the wall vertical, noting that surfaces will be flat and level within normal building tolerances. The distance to the vertical wall will be varied over three ranges for the competition heats, and teams will make attempts at each of the short, medium and long-range distances.

2.1 Lane Area

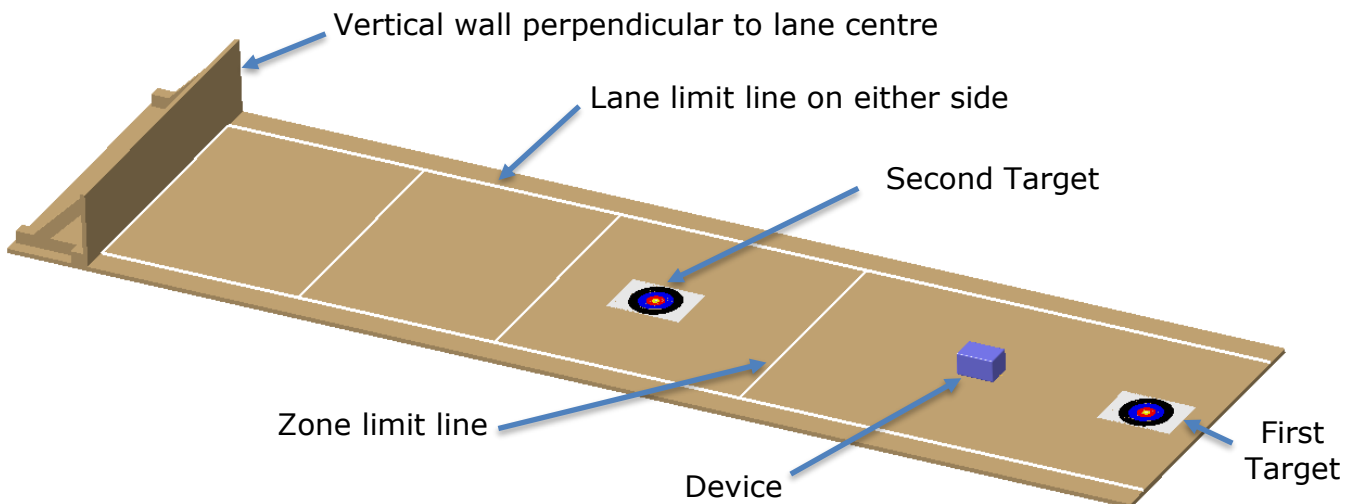


Figure 4. Typical lane set-up with the wall set at the maximum range distance. A STEP file of this assembly is available in the Competition Resources section of the IMechE Design Challenge website.

The range distances (minimum to maximum) are shown in Figure 4 and are as follows:

Short range	1.4m – 2.4m
Medium range	2.4m – 3.2m
Long range	3.2m – 4.0m

2.2 Second Target Position

The position shown in Figure 4 is arbitrary and for illustration only.

The distance between the first and second target points will be different for each range.

The second target position does not have to be in the same range as the wall.

No matter what range distance is chosen, the location of the second target will be no closer than 0.5m to the wall and at least 0.9m from the first target.

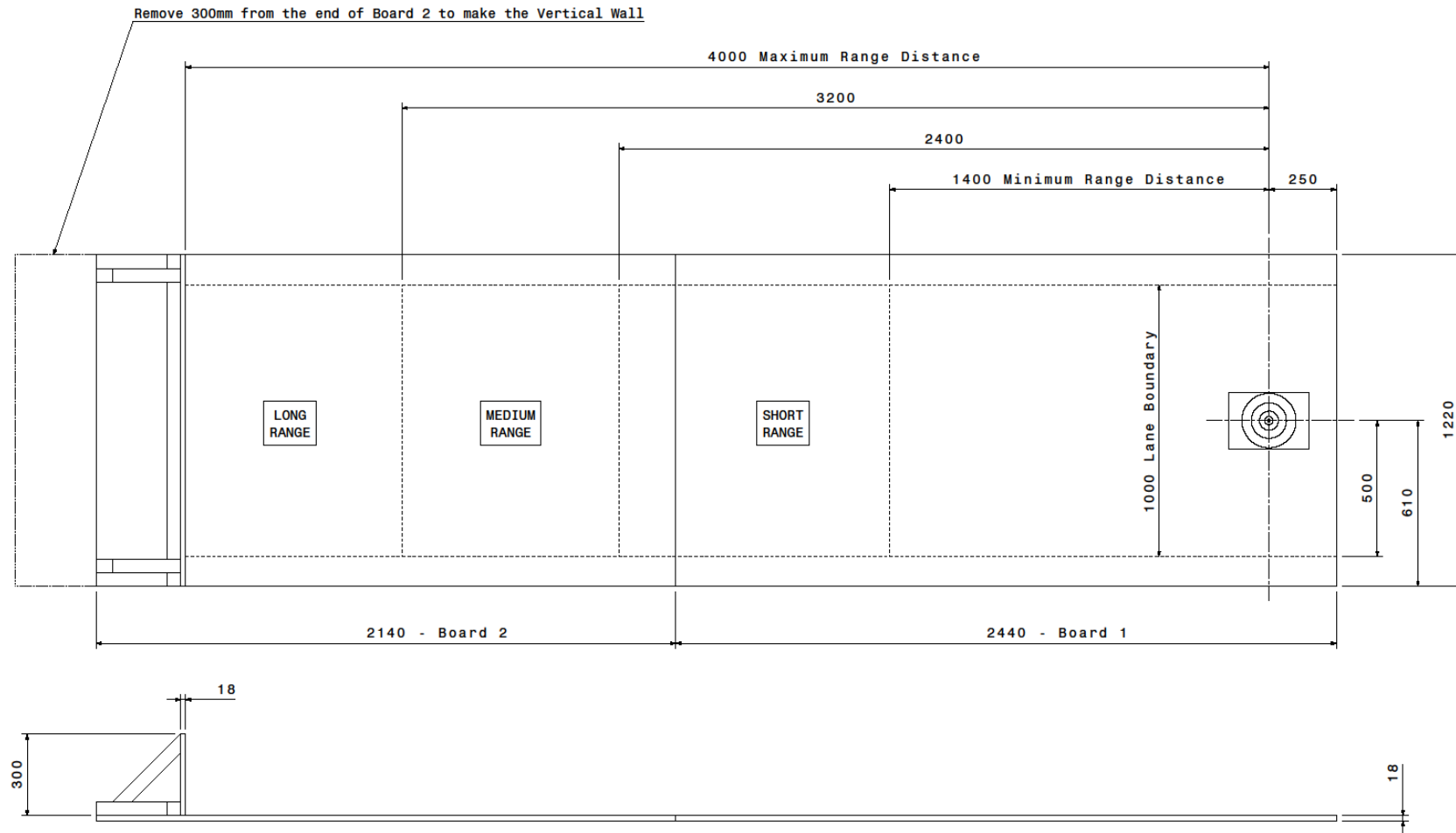


Figure 5. Typical lane set-up with the wall set at the maximum distance. All dimensions in millimetres. All tolerances $\pm 10\text{mm}$ unless otherwise stated. Angular tolerances $\pm 5^\circ$. A DXF file of this diagram is available in the Competition Resources section of the IMechE Design Challenge website.

The lane will be a flat, horizontal, wooden surface; the wall will be 0.3m high, vertical, rigid and heavy.

For each range, target distances will be chosen by the organisers on the day of competition between the min. and max. limits, at intervals of 0.05m (50mm) within a tolerance of $\pm 0.01\text{m}$ ($\pm 10\text{mm}$).

The target distances will not be announced to competitors. This is so that the distance is measured autonomously by the device and to ensure teams do not have a programmable system. Consistency amongst heats will be maintained within the spirit of the competition.

Examples of suppliers for all the equipment and materials are given in Appendix 1.

2.3 Target Area and Scoring Zones

There will be a series of circles around the target points and each band between the circles represents a number of points; the highest score being the target centre and then the points becoming progressively fewer as the circles increase in diameter.

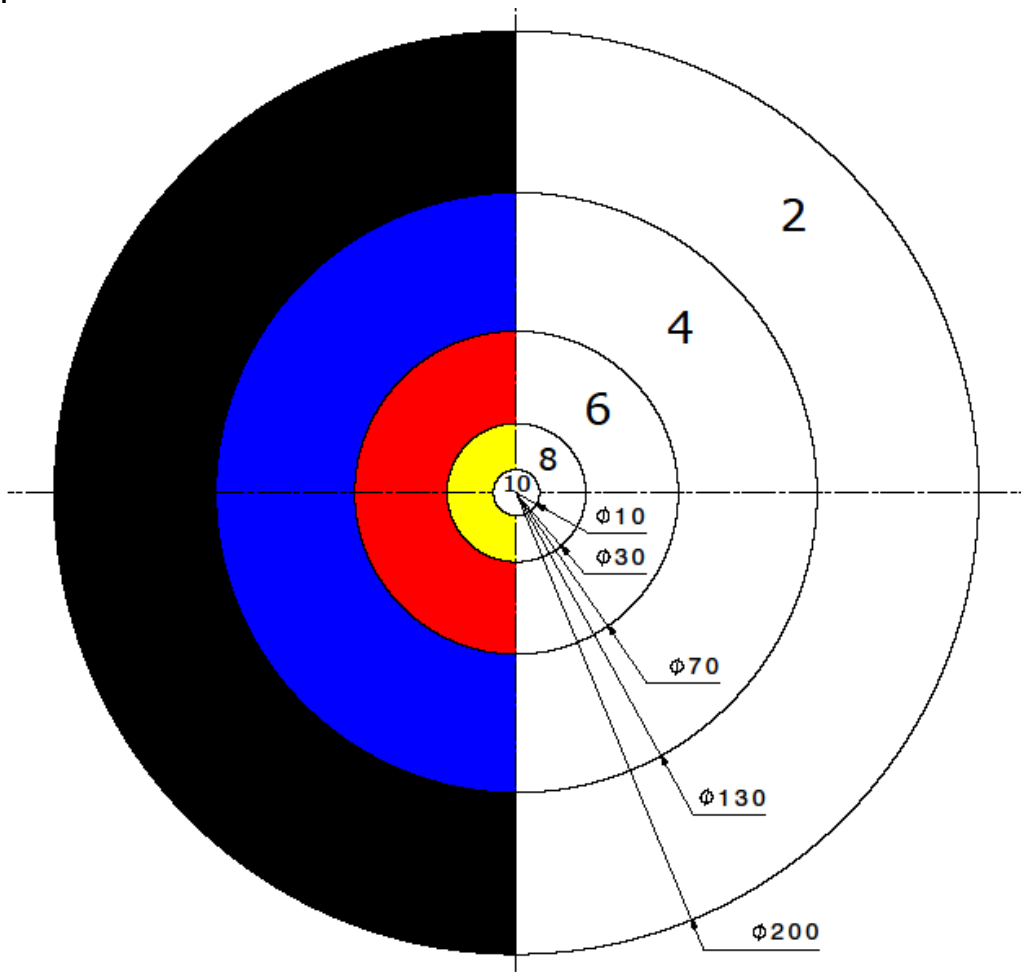


Figure 6. The Target Area and Scoring Zones (not full size). The bullseye is worth 10 points.

A printable Target Area is included in Appendix 2.

2.4 Datum Point

Scores are determined by a datum point mounted on the device, which is aligned with the centre of the target at the start of a run. The score is determined by the position of the datum point at the end of the run. If the datum point is on a line between scoring zones, the higher score will be given.

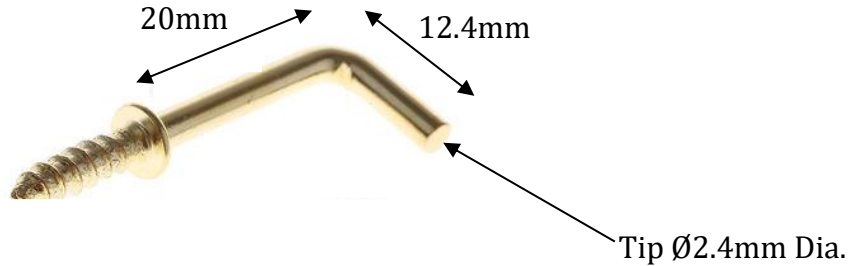


Figure 7: The Datum Pointer - details of the supplier are included in Appendix 1.

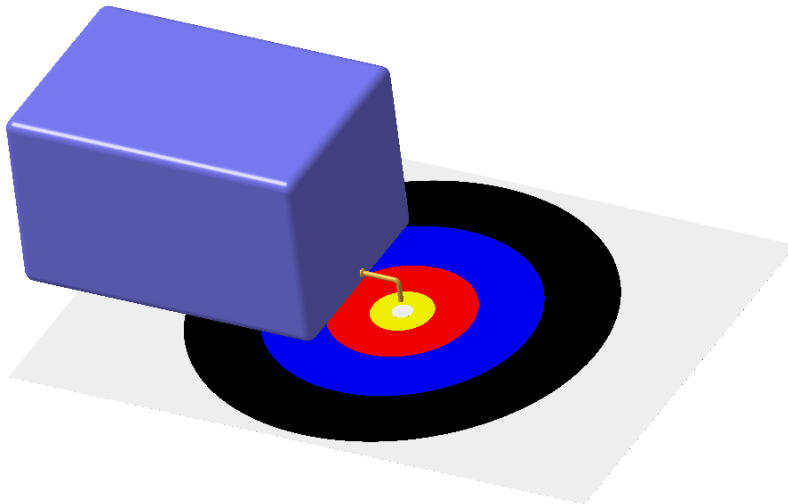


Figure 8: Position of the Datum Pointer at the rear of the device relative to the Target Area at the start of a run.



Figure 9: The Datum Pointer must be no more than 6mm above the lane surface.

3. Technical Regulations for the Device

- 3.1 Each team shall produce one single device.
- 3.2 The device can be of any type, but it must be totally self-contained, and at all times during the competition fit within a working envelope of 400mm x 400mm x 400mm. On the day of the competition this will be checked using a gauge.
- 3.3 Nothing used by the device to navigate or move can be outside that volume during the race (no remote control, power leads, laid tracks, left behind markers, gps etc.)
- 3.4 The device must fit within the maximum working envelope at all times during competition, even when in motion.
- 3.5 The final position of the device will be determined from a datum point on the rear of the device. The datum point will be the tip of an 'RS Pro Steel Brass Plated Square Hook 20mm', which is to be held in the vertical position. The square hook must be securely fastened to the rear of the device.
- 3.6 The device must be fully autonomous during the entire process after the start switch has been pressed.
- 3.7 No proprietary, pre-programmed control units or devices may be used.
- 3.8 Parts from existing devices (i.e. chassis, drive systems, suspension, etc.) are not permitted.
- 3.9 The device cannot be operated wirelessly at any time, nor can it be controlled remotely.
- 3.10 Any electrically operated device must be fused appropriately to the motor maximum operating current. If motor maximum current cannot be proven, a maximum current draw of 10A is permitted.
- 3.11 It is permissible to replenish the device's energy source between heats. Competitors should consider this during their design process so as to minimise disruption to the smooth running of the event. Any team not ready to compete within three minutes of being called will be disqualified.

4. Rules for the Main Competition

- 4.1 All devices must be available for scrutineering prior to commencement of the competition.
- 4.2 No practice runs are permitted on the lanes, but devices may be tested elsewhere for all other functionality.
- 4.3 Clear instruction on the running order for the heats and finals will be given at the event.
- 4.4 All teams must display an A4 sheet detailing the teams name and University and this must be clearly displayed as instructed during any run in which the team is taking part.
- 4.5 There will be three competition lanes in the Main Competition, set at different wall distances.
- 4.6 The wall distances will be the same for all teams, but will not be known in advance, and will be determined on the day.
- 4.7 Organisers will not announce the target distances during the competition and teams are not allowed to measure the distance using a tape or any other means.
- 4.8 Teams will compete head to head in heats for a place in the final. The relative performance will be determined by teams scoring points during a run.
- 4.9 A heat or final will involve running on each of the three lanes. Therefore, each team will have a single run at the wall in each of the three different wall distances.
- 4.10 Heats may consist of up to three teams' devices running in parallel on different lanes. Each team must compete in two heats (i.e. 2 x 3 runs). Scores will be recorded for each successful attempt.
- 4.11 Participating teams will have a maximum of 3 minutes before a heat to prepare and position their device on the target centre.
- 4.12 Teams not ready within the allotted time before a heat or final will forfeit that attempt.
- 4.13 The time limit for runs in the heats and final will be 2 minutes. Time will start from the end of the timekeeper's starting countdown.
- 4.14 In a run, the vehicle will have one attempt to reach both of the target points. The run is scored on accuracy alone, not on speed, but the run has to be completed in the allocated 2 minutes.
- 4.15 Each team must appoint a 'Device Controller' who will be the only person to attend to the device during the preparation and start of each run.
- 4.16 During a run all other team members must be outside the test area. A judge will be allocated to each test area to ensure the correct procedure is followed.

- 4.17 If a device is started before the starters order it will forfeit that attempt.
- 4.18 If a device fails to start within 10 seconds of the START command during a run it will not score points for that attempt.
- 4.19 Repairs and minor alterations are allowed to the device between each run within a 2-minute time limit.
- 4.20 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 the competition.
- 4.21 A video camera will continuously film the activity in the competition lanes so that if there is a dispute it can easily be resolved.
- 4.22 Breach of any rule during competition will forfeit that heat or final.
- 4.23 Continued breaches or behaviour unbecoming of the spirit of the challenge will result in the team being disqualified from the competition.
- 4.24 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. Main Competition Run Procedure

- 5.1 Team Device Controllers put devices in the test area with the device aligned and the datum point over the target centre.
- 5.2 Judges check position of datum point and device readiness.
- 5.3 Device Controllers will raise their hand clearly to show readiness within the three-minute period. If all the teams are ready, a run can commence.
- 5.4 When teams are ready the 'Timekeeper' will give a clear "3,2,1 Go!"
- 5.5 The Device Controller will start the device manually and then stand clear of the test lane.
- 5.6 The attempt ends when a device has stopped.
- 5.7 Judges will check the position of the datum point relative to the targets and record the scores for that run
- 5.8 The device cannot be touched until the judge signifies that the run is complete. This means that the device cannot be switched off manually until this point.
- 5.9 The Device Controllers will collect their devices when authorised by the judges. Minor repairs and adjustments can be made at this stage.
- 5.10 The run procedure is repeated on each of the three lanes to complete a heat.

6. Scoring for the Main Competition

- 6.1 For scoring purposes, phase one of the run is considered complete when the vehicle has come to rest for more than 5 seconds when travelling away from the wall. Phase two commences once the vehicle starts to move in a direction back towards the wall.
- 6.2 After each single run the distance from the vehicle datum to the first target point (phase one) and the second target point (phase two) will be scored and recorded.
- 6.3 Judges will determine points from the scoring rings around the target area.
- 6.4 After the three single runs the six scores recorded in the heat will be added together.
- 6.5 The highest of the two heat scores will be used for a team's total points.

Regional Finals

- 6.6 A maximum of 60 points is available in the heats. The top three teams in the heats returning the highest scores will progress to the final.
- 6.7 Points from the heats will not be carried forward. A maximum of 60 points is available in the Regional Final. The winner will be the team achieving the highest score in the final.
- 6.8 In the event of a tie in the Regional Final, a re-run between the tied teams will take place as detailed in Sections 6.14 – 6.16.

National Finals

- 6.9 A maximum of 60 points is available in the heats. The top three teams in the heats returning the highest scores will progress to the final.
- 6.10 Points from the heats will be carried forward to the final. 60 points are available in the final, meaning a maximum of 120 points is possible for the Main Competition.
- 6.11 Points from the Main Competition will be halved to add to the Design Challenge total score out of 100.
- 6.12 In the event of a tie of overall points in the National Final, the team with the highest points in the Main Competition will be the winner.
- 6.13 In the event of a further tie on points, a re-run between the tied teams will take place as detailed in Sections 6.14 - 6.16.

Re-Run Procedure

- 6.14 In the event of a tie affecting qualification to the final, the tied devices will be retested in each of the three lanes. Points will be accumulated as in the heats.
- 6.15 If a winner cannot be determined after the tie re-run, there will be a head to head run off on the longest distance lane for a single run score.

- 6.16 If this does not determine a winner on points the distance to the datum point on the second target will be measured and the device with the shortest distance will be the winner of the tie.
- 6.17 In the unlikely event that the tied vehicles consistently land in the bullseye and cannot be separated by distance, the time taken will be recorded. Assuming both teams score a bullseye, the team with the fastest time to complete the run will be the winner.

Zero Points

- 6.18 A team will score zero points:
- if a device does not hit the wall,
 - if a device leaves the lane
 - if a device does not stop within the target area around the datum point
 - if a device has not come to a stop after 2 minutes, or
 - if a device, or its team, does not comply with the competition rules.
- 6.19 A device disqualified from one of its runs can still take part in the other attempts.

7. Rules for the Design Competition

In the real world, virtual prototyping and simulation can significantly reduce development times and costs. Product development requires a judgement to be made between this and the level of physical prototyping and testing that is required. A balance has to be found to ensure that a high-quality, durable, reliable product is delivered to budget and on time.

To demonstrate their ability to create a virtual concept, teams are required to submit a virtual prototype of their design. The ultimate aim is to produce a 100% realistic model of the design, which is accurate in every detail, so that it represents exactly what will be built. The Computer Aided Designs (CAD) will be submitted to the judging panel ahead of the competition date.

Virtual designs will be judged on their real-world accuracy. Teams should pay particular attention to physical similarity, not just in form, but also in terms of mass and inertia and level of detail.

- 7.1 Teams are required to submit a fully-detailed virtual design of a device that will complete the IMechE Design Challenge.
- 7.2 The virtual prototype must match the device that competes in the Main Competition and will be judged for similarity on the day.
- 7.3 In terms of physical similarity, assemblies must include the finer detail, such as fasteners.
- 7.4 Wiring is one of the most difficult items to model in 3D. Teams are encouraged to attempt to model wires to gain experience, but this will not form part of the scoring.
- 7.5 The virtual prototype is to be submitted in STEP format via the IMechE Design Challenge website. Details will be circulated to teams at the time.

- 7.6 Teams are strongly advised to check the integrity of their STEP file before submitting it, to check for any translation errors, and to ensure that it includes the complete assembly of the device with no parts missing.
- 7.7 Submitted models must be an assembly of individual solid bodies, and not one single entity.
- 7.8 Individual parts within the assembly must be solids with mass and volume, and not surface models, which are just a shell.
- 7.9 Teams must submit a Bill of Materials (BOM) to accompany their virtual prototype. The BOM must include the following information for each item, in the BOM template that will be provided:
- Part Name
 - Part Number
 - Quantity
 - Material
 - Density – in kg/m³
 - Mass – in kg
 - Cost – in £0.00
 - Supplier
 - Hyperlink to supplier’s website
- 7.10 Every individual item must be included in the cost entry in the BOM. This includes items costing less than 20p.
- 7.11 The BOM template will have two sections, one for items costing more than 20p, and one for items less than 20p.
- 7.12 Material and density properties are included so that judges can verify the accuracy of the model by applying material properties to individual components to check the calculated masses and inertias provided in the BOM.
- 7.13 Virtual prototypes must be submitted no later than 2 weeks ahead of the date of the Regional Competition or National Final.
- 7.14 Please read the document “IMechE 1st & 2nd Year Design Challenge - General Specification 2021” for all other Design Competition rules and scoring.
- 7.15 A maximum of 10 points is available for the Design Competition.

8. Rules for the Poster Competition

- 8.1 For the National Final, please note – The Poster should be submitted to the IMechE electronically via email – designchallenge@imeche.org - no later than one week before the date of the final. This allows for judging prior to the competition to save time on the day.
- 8.2 Each team should display their poster on the board provided and display their device on the table below their poster.
- 8.3 Please read the document “IMechE 1st & 2nd Year Design Challenge - General Specification 2021” for all other Poster rules and scoring.

8.4 A maximum of 10 points is available for the Poster Competition.

9. Rules for the Presentation Competition

9.1 For the Regional Competition, the maximum length of the Presentation is five minutes plus, typically, two minutes for questions.

9.2 For the National Final, the maximum length of the Presentation is seven minutes plus, typically, three minutes for questions.

9.3 Please read the document "IMechE 1st & 2nd Year Design Challenge - General Specification 2021" for all other Presentation rules and scoring.

9.4 A maximum of 10 points is available for the Presentation Competition.

10. Rules for the Peer Review Competition

10.1 The peer review takes place in the Regional Competition.

10.2 Each team should examine the device from all of the other teams without handling them.

10.3 Whilst the peer review is being carried out there must be at least one member of each team present to answer questions etc.

10.4 Please read the document "IMechE 1st & 2nd Year Design Challenge - General Specification 2021" for all other Peer Review rules.

10.5 A maximum of 10 points is available for the Presentation Competition.

11. Rules for the Design Excellence Competition

11.1 The design excellence review takes place in the National Final.











11.2 Each team should display their device on the table beneath their poster.

11.3 Whilst the design excellence judging is being carried out there must be at least one member of each team present to answer questions etc.

11.4 Please read the document "IMechE 1st & 2nd Year Design Challenge - General Specification 2021" for all other Design Excellence rules.

11.5 A maximum of 10 points is available for the Design Excellence Competition.

Appendix 1 – Equipment List and Suppliers

	<p>Datum Point – Option A: RS PRO Steel Brass Plated I Hooks 20mm Code: 397-4954 https://uk.rs-online.com/web/p/square-hooks/3974954/</p>	 RS-397-4954.pdf	<p>£1.44 Bag of 10</p>
	<p>Lane Board – Option A: Smooth Hardwood Plywood Board by B&Q (L)2.44m (W)1.22m (T)18mm Code: 1696280 https://www.diy.com/departments/smooth-hardwood-plywood-board-l-2-44m-w-1-22m-t-18mm/1696280_BQ.prd</p>	 B&Q-1696280.JPG	<p>£34.00 per sheet - 2 sheets per lane</p>
	<p>Lane Board – Option B: Structural Plywood Board by Travis Perkins (L)2.44m (W)1.22m (T)18mm Code: 9000148434 https://www.travisperkins.co.uk/plywood/selex-structural-plywood-bc-grade-2440mm-x-1220mm/p/9000148434</p>	 TP-9000148434.JPG	<p>£39.34 per sheet - 2 sheets per lane</p>
	<p>Lane Board – Option C: Smooth MDF Board (L)2.44m (W)1.22m (T)18mm Product Code: 1696262 https://www.diy.com/departments/smooth-mdf-board-l-2-44m-w-1-22m-t-18mm/1696262_BQ.prd</p>	 B&Q-1696262.JPG	<p>£22.48 per sheet - 2 sheets per lane</p>
	<p>Wall Support – Option A: Redwood Planed Timber 50mm x 50mm x 2.4m (Finished size 44mm x 44mm) Product Code: 491883 https://www.travisperkins.co.uk/planed-softwood-timber/redwood-planed-timber-50mm-x-50mm-x-2-4m-finished-size-44mm-x-44mm/p/491883</p>	 TP-491883.JPG	<p>£4.97 per 2.4m length - 1 length per wall support</p>

Appendix 2 - Target Area

The Target Area must be printed on a white gloss background on a single A4 sheet as a peelable sticker. The RGB colour codes are , from outer to inner: Black 0,0,0; Blue 0,0,255; Red 255,0,0; Yellow 255,255,0; White 255,255,255.

A printable version of the target is shown on the next page with the correct dimensions and colours.

Any deviation from these regulations must be approved.

