Design for Manufacture (DfM) DEN5101

DEN5101 DfM Coursework Brief (SEMB 2016)

The design for manufacture of a self-contained autonomous electrically powered robot to lift an increasing load vertically up a copper pipe, which uses sensors and control systems to move the robot to a precise position after a number of operations.

In collaboration with

The IMechE Inaugural Design Challenge Competition organised by the Institution of Mechanical Engineers and universities in the Greater London Region for second year undergraduates.

Note: Use the relevant sections of the attached document for the DEN5101 coursework submissions, i.e., building, testing, posters and presentations will take place within a the regional completion rather than for this module coursework (see table below).

CW No.	Coursework Title	Submission Date	Weighting
CW1	DfM Brief, Initial Product Design Requirements Specification (IPDRS), Literature Search Table and Gantt Chart.	Week 18 *(Week 3 of SEM B)*	25%
CW2	DfM Report: Final Product Design Specification (FPDS), Control Algorithm and Engineering Drawings for Manufacture	Week 24 *(Week 9 of SEM B)*	60%
CW3	Peer Assessment	Week 25 *(Week 10 of SEM B)*	15%

Table of Contents

1 Introduction and summary

This is the Inaugural Design Challenge Competition organised by the Institution of Mechanical Engineers and universities in the Greater London Region for second year undergraduates. This year the student Design Challenge is set in the context of lifting equipment, and is an extension of the 2015 first year competition to include the use of sensors and control systems. There are many applications of such devices in engineering such as lifts, cranes, ski lifts, machine tools etc.

The challenge is open to teams of up to 5 students on the Second Year of an Engineering course at a University in the Greater London Region.

The Challenge involves five elements:

- Work in a team to design, build and test a self contained autonomous electrically-powered robot to lift an increasing load vertically up a copper pipe, using sensors and control systems to move the robot to a precise position after a number of operations.
- Compete with other teams to produce the fastest device
- Produce a poster and brochure to explain and publicise the team's work
- Deliver a presentation explaining the rationale for the team's work
- Take part in a peer assessment to determine the "best" design.

The "compete" element involves a race, with the robot moving from the bottom of a copper pipe to the top and returning to the bottom, constituting one cycle, for three complete cycles and then moving down from the top of the pipe to a specified position half way down the pipe on the 4th cycle and stopping. The winner of this element is the team that achieves this procedure in the shortest time closest to the indicated position. Penalty times will be awarded for lack of accuracy in achieving the final position such that a position in error of greater than ±10 mm will be penalised by 2 seconds and greater than ±20 mm by 5 seconds etc. If the robot does not stop on the fourth cycle and returns to the bottom of the rig then there will be no points for that leg of the heat cycle.

The judges may vary the rules within reason to ensure a fair and satisfactory competition in the time available.

2 Equipment

A schematic of the rig to be used in the Design Challenge is shown in Figure 1 below. Key features include:

Robot

- A lifting robot that fits within a cylindrical envelope of 200 mm diameter (centred on a hole large enough to allow free passage of a 15 mm diameter pipe) and 200 mm maximum height. This is the robot to be designed by the competing teams. The upper surface of the device should include an annular disc of not less than 3mm thick and 200mm diameter, inner diameter to clear the 15 mm pipe, centrally positioned around the copper tube to enable precise measurement of final position to be made. The robot must actuate a micro switch on the main rig to enable indication that each full cycle has been completed.
- A chain, 2500 mm in length, cut from a piece of chain, Screwfix catalogue number 88926. The approximate mass of this chain is 0.3 kg/m.

  See also Figure 2.
- The robot can be powered by any suitable motor that fits the specification of the robot.

  Rig
- Standard domestic copper plumbing pipe of 15 mm outer diameter and 2500 mm active length is used.
- A rigid stop to mark the vertical limit of the pipe and prevent overrun. The pipe will be supported to prevent lateral swaying.

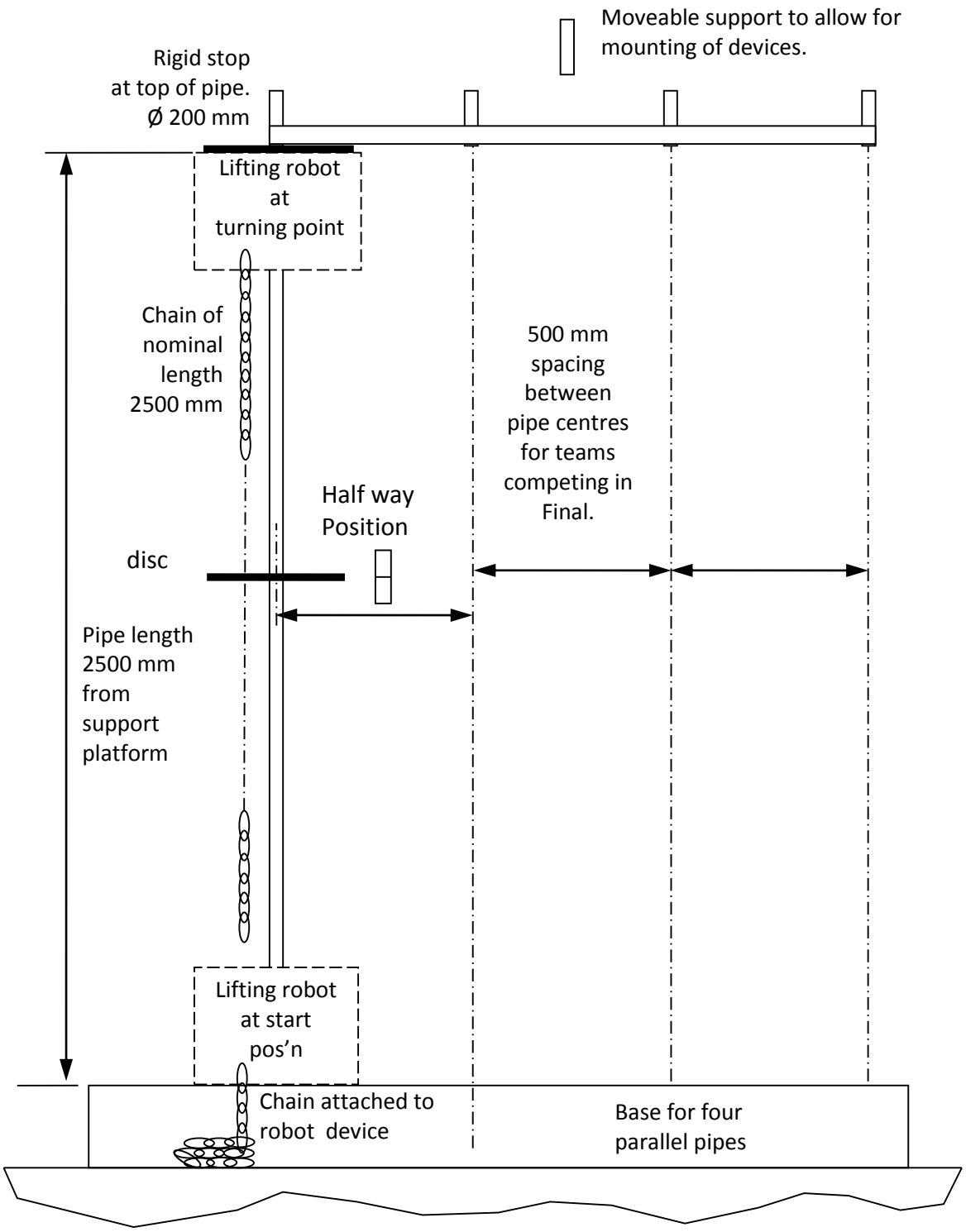

Figure 1. Schematic of design challenge rig

3 Competition Rules in Detail

a) The competition is open to students in the second year of undergraduate engineering courses at the participating London Universities. The inaugural pilot competition date and place to be confirmed.

b) Each University is allowed to enter one team of up to five students each. Each team may use only one device.

c) All teams in the regional competition must participate in the design-make-test-compete ("race") event and the peer review event. Each team must produce a brochure describing their device with full design calculations and relevant decisions with full costing and trial data.

d) Each university team must compete in the poster element and the presentation element. The elements are marked independently on the day; performance in one does not affect the mark in another.

e) All teams in the regional competition will receive a certificate of attendance. There will be winners and runners up certificates for the first two teams in the design-make-test competition, for the first in the poster competition and for the first in the presentation. An additional certificate will be awarded to the "best design" only, as judged by the participating competitors through peer assessment. The outright winning team will be decided based on the total points achieved during the competition and a prestigious trophy awarded to the winning team.

f) The 'robot' must be self-contained and at all times during the competition fit within a cylindrical envelope of 200 mm diameter and 200 mm height, as shown in Figure 2 below.

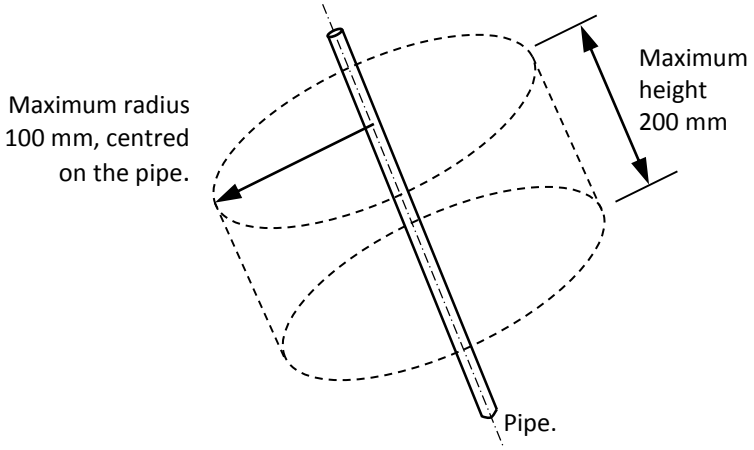

Figure 2. Space envelope for the lifting robot.

g) Each robot 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 robot to violate the dimensions shown in Figure 2. Failure of the attachment or loss of the chain will result in disqualification from the heat.

h) Electric motor and other drive-train items – battery box (es), wiring, gears and shafts, for example – must be selected and purchased or designed, made and assembled by the team. Controlling devices whether by discrete components or devices such as an Arduino should be mounted on the device. Programming instructions should be shown in the device brochure.

i) A full parts list must be produced. Receipts must be provided ahead of the competition for inspection by other teams and included with the brochure. The total cost of the device (including VAT at 20%) is to be under **£50**. Prices for components costing more than £0.20 will be checked against the standard price list of established suppliers.

j) All parts must be listed with the **as-new normal retail purchase price from established suppliers** (including VAT but excluding carriage). UK supplier retail prices, which have been displayed for at least one year, are required to be used. Components must be those supplied by the lawful patent holder. Note that while actual prices paid by teams for items may be below retail price, it is the price advertised by the suppliers that must be used in cost calculations. Invoices and receipts are required to be included with the brochure.

k) Parts with a value of less than £0.20 should be included on the parts list but do not need to be included in the total price (considered free). Components in-kind or provided by the University must be included in the parts list.

l) The cost must include all parts and materials on or over £0.20 used to make the robot and any replacement or substitute parts used during the final event. The onboard power supply is to be included in the £50. Any spare sets of batteries for example to be changed during the heats need not be counted towards the £50.

m) While the cost of generic tools (drills, saws, files, etc.) need not be included, specialised and unique tools need to be accounted for. For example, a machined wooden former costing £5 used to vacuum form a part during construction must be included as it is bespoke to this item; however the milling cutters used to make the form need not be included. Likewise a battery charger or air compressor can be excluded as they are considered general-use workshop items.

n) Standard sheet/bar materials should be charged as a proportion used per robot, within reason. For example if the purchase of a 6 m length of steel bar cost £18 and 200 mm were used, the cost recorded would be £0.60 (£18 x 0.2 / 6.0). Purchase of 600 m of bar would be deemed unreasonable.

o) The costed parts list & invoices must be clearly displayed by all teams during static judging and scrutineering. Teams may be expected to justify the purchase price of any item of the device, whether on the parts list or not. All robots must be 'signed off' by the academic staff member of the individual Universities to say that their teams' robots meet all of the scrutineering rules concerning cost, before the final competition. On the day of the competition after successfully completing the scrutineering process teams will be given a sticker, this must be attached to the device as proof of scrutineering. Any team which try to enter a heat without this sticker will not be allowed to compete.

p) No adhesive or lubricant is to be used between the device and the pipe. Robots must not cause any change to, nor leave any debris on the surfaces of the pipe.

q) 3D rapid prototyping or additive manufacture is permitted but for components only and NOT used for constructing the the whole device. CNC-machined and 2D laser- or water-jet-profiled parts are allowed providing that the basic design work is demonstrably that of the team's members.

r) Energy storage may take any safe and reasonable form, having regard to the amount of energy required for the device to take part in the race heats and final.

Lithium-Polymer batteries are allowed, but if they are used, for safety reasons must be limited to 7.4V ("2S") size and of no more than 500 mAh capacity. If such batteries are used, an inline fuse of 5A or less must be fitted. The fuse must be removed immediately after each run. This limitation does not apply to other batteries.

s) All robots must be 'signed off' by the relevant academic staff member of the individual Universities to confirm their robot adheres to safety procedures.

4 Competition (Race) Procedure

This is the core of the Challenge, where the teams demonstrate an ability to produce a design solution and compete with other teams.

a) The race competition will consist of first-round group heats (up to a maximum of four) followed by a final. Universities will randomly be put in heats with each team within the group competing against each other to win points. Appendix A shows the progression process in principle.

b) All teams will be given an A4 sheet of paper displaying the team's name and university (e.g. Kingston A, Brunel B); this must be clearly displayed as directed by officials during any run in which the team is taking part.

c) The test area will consist of four identical pipes to allow for simultaneous runs of up to four robots, as per Figure 1. Each pipe is made from standard copper domestic plumbing pipe 15 mm diameter and has an exposed length of 2500 mm. At the start of each run, one nominated student (the "human robot controller") from the team will fit the robot onto the bottom of the pipe before starting. The robot must have a single easily-accessible starting switch.

   The mounting arrangement of all the pipes will allow for lifting the pipe clear of its base, should the robot need it. Nonetheless, "clamp-style" fitting of the robot is allowed.

d) The human robot controller from each team will start that team's robot on completion of a countdown given by a single timekeeping judge ("Three-two-one-GO!"). There may be a random wait between "one" and "GO". Having started the team's robot each human controller must then step away from the pipe.

   False starts in any run will not trigger a re-run; any team judged to have started before the "GO" signal will be disqualified from that run and score no points for it.

e) Each heat will consist of four robots running simultaneously. Bonus points will be scored as follows:

   - 10 points will be awarded for the overall minimum time
   - 5 points will be awarded for the next minimum time
   - 2 points will be awarded for completion of the whole stage in a time less than the two best times

- In order to award these points robots that are within ±10 mm of the required final position will have no time penalty and their measured time will stand as declared. Those that are within ±20 mm will have 2 second added to their measured time and greater distances pro rata. These modified times will be used to determine the teams' overall points score. The whole heat must be completed by each team within 3 minutes.

- When a device finishes parts of the stage points will be awarded as follows:
- *Completion of the first part of one cycle* *1 pt*
- *Completion of one cycle* *2 pt*
- *Completion of one and a half cycles* *3 pt*
- *Completion of two and a half cycles* *5 pt*
- *And so on*
- *Completion of three and a half cycles* *7 pt*
- *Completion of whole task* *10 pt*

- First place is achieved by the device with the maximum score.

- The four teams with the most points accumulated after all heats will progress to the final. The progression process is shown schematically in **Appendix A.**

f) At the end of each robot's run, the human controller must safely disable the propulsion system.

g) A judge will be allocated to each competition pipe to ensure the rules are adhered to and use a digital stopwatch to manually time that pipe's device on its bottom-top-bottom round trip.

A further judge will start and oversee each heat, then declare the finishing order for that heat.

In the event of a disputed result or a tie then a runoff between the two teams will be made.

The video camera shall be positioned so that it captures the entire competition rig ensuring that all four pipes are fully and clearly visible.

h) The time limit for the heats and final will be three minutes. Time will start from the end of the timekeepers starting countdown.

i) If a robot does not meet the requirements of Section 3 above, and modification cannot be made to allow it to comply before its allotted starting time, then it will be disqualified from the heat.

j) The load (chain) must remain attached at all times during the run, otherwise no points will be scored in that run.

k) Should there be a technical fault to the rig (not robots) deemed to unfairly disadvantage a team, times and positions from the first run will be discarded and there will be a rerun.

l) The organisers will record times and resolve ties efficiently so as not to interfere with the smooth running of the event.

m) It is permissible to replenish the robot'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 five minutes of being called may be disqualified from the heat but judges are allowed discretion to vary the rules to keep the competition running successfully.

5 Rules for the Poster

The Poster, robot and brochure are to be displayed together in a separate area at the start of the competition with a member of the team present to answer questions from the judges.

The poster is a demonstration of the team's ability to sell its design solution using graphical and pictorial skills.

a) The team from each University enters the poster competition.

b) The poster shall be A0 size in portrait format. It must clearly display the logos of the team's University and of the IMechE.

c) The poster should concisely describe the device, how it operates and the engineering principles it is based on. In producing their posters, participants should take account of the judging criteria in **Appendix B**.

d) A summary of the costs must be included.

e) The brochure should be available for inspection

6 Rules for the Presentation

The presentation is a chance for a team to sell its design solution to the Challenge using verbal and presentational skills.

a) The team from each university enters the presentation competition

b) Presentation data files should be submitted to the organisers' IT/AV representative **on arrival** at the final event. The format shall be Microsoft Powerpoint 2010 (*.pptx*) or Adobe Reader X (*.pdf*), to be run under Windows 7 on a generic PC. The storage medium should be a USB data stick, and the data files will be copied to UCL's own server for later use by the IMechE.

c) Students should not assume the availability of a connection to cloud-based storage or other remote resources. Presentation from students' own laptops ***may*** be possible but only a VGA analogue interface can be guaranteed, and no compatibility of display resolution is guaranteed.

d) DVI, HDMI, Apple Mac, AirPort, wireless, DisplayPort and other interfaces cannot be guaranteed and should be assumed to be unavailable.

e) The presentation must include how the robot works, the drive system, power management and sensors. The presenters should discuss on a rigorous basis how design choices were made and how the project was managed. Finally the predicted performance should be given. Students will be allowed – and are encouraged – to test their presentations as soon as possible on arrival, and make sure that they work with the UCL AV equipment.

f) The maximum length of the presentation is five minutes, plus typically two minutes for questions. It can be delivered by any number of team members, from one person to all members of the team.

g) In producing their presentations, participants should take account of the judging criteria in **Appendix C.**

h) Presentations will be assessed according to the scheme in Appendix C and will be judged by one representative from each university. Universities will not mark their own presentation.

i) Each team will be required to answer questions on their design.

6 Rules for the Peer Review

a) Teams will clearly display their robot along with the costing sheet in the designated spaces provided. All teams will then review (without touching or handling robots) all the other participating teams. Each team should make at least one member available throughout the peer review process to engage in discussion and/or demonstration of its robot's features.

b) Teams are asked to select and rank the top three designs they judge to be the "best designed" and vote for them by completing the slip an example of which is shown in **Appendix D**.

c) There will be only one voting slip for each team; competitors may not vote for teams from their own university.

d) The team with the most "first votes" will win the peer review.

e) In the event of a tie, "second votes" (and then "third votes") will be counted. The points will be added to the totals to enable the overall winning team to be evaluated.

f) Enforcement of the Rules

Current Rules will be displayed on the Competition web site and comments or queries may be addressed to Professor White up to 1 month prior to the competition.

7 Judging Requirements

a) On matters relating to test equipment and procedure, the authority will be the chair of the IMechE Design Challenge organising committee or his/her delegated representative(s).

b) The judging panel comprises one representative from each of the participating universities, the Chair of the organising committee and the IMechE's Engineering Director and a head judge from GLR.

c) The decisions of the panel of judges will be final.

d) In addition to the rules for the final outlined above, universities are responsible for internally ensuring that the *spirit of the competition* is adhered to during the design, make and test stages prior to the competition Final.

e) If a team wishes to lodge a complaint or appeal, or to query a procedure or rule infringement they must do so through the chair of the organising committee or delegated representative. The result of the subsequent decision is final, with no further appeal.

8 Prizes

These are under discussion at this time.

Appropriate certificates of recognition will be awarded to all students and the winning institute.

---------- End of Main Document. Appendices A-D follow ----------

APPENDIX A – Schematic of heats and progression process

To Be confirmed

APPENDIX B – Poster judging criteria

		Weight (%)
Visual impact	Compliance with rules – size (A1) and orientation (portrait)	**15**
	Obvious information on the university represented (logos) and the team members' names	**15**
	Good use of colour, layout, text and space to convey meaning	**15**
Technical Content	Clear but brief textual description of the competing device	**15**
	Clear diagram(s) – sketch, rendering or CAD model – of the device	**15**
	Evidence of the engineering science underpinning the device	**15**
	Summary costing of major components of the device	**10**
		100

APPENDIX C – Presentation judging criteria

		Weight (%)
Presentation style	Audience Engagement	**15**
	Quality of spoken presentation (well structured, fluent, clear etc.)	**15**
	Quality of visual aids (clear and easily readable, do not duplicate spoken presentation etc.)	**15**
Technical Content	Principal features of the final design	**15**
	Steps followed to reach the final design, including costing of the device	**15**
	Engineering science that underpins the final design	**15**
	Answer to judges questions	**10**
		100

APPENDIX D – Peer review voting slips

Team voting:_____

We have reviewed the other teams' designs and would rank the top three "best designs" as:

1st _____

2nd _____

3rd _____

Team voting:_____

We have reviewed the other teams' designs and would rank the top three "best designs" as:

1st _____

2nd _____

3rd _____

Team voting:_____

We have reviewed the other teams' designs and would rank the top three "best designs" as:

1st _____

2nd _____

3rd _____