GIZMO

GIZMO STUDENT HANDBOOK

DE2-GIZ GIZMO, 2016-17

Module Leader: Andrew Brand

Handbook version: 1.7

Dyson School of Design Engineering

Imperial College

Comments and corrections to andrew.brand@imperial.ac.uk

Lecture resources may be found on Blackboard

NOTE words that are highlighted and underlined are hyperlinks

INTRODUCTION

Gizmo combines the approaches of physical computing and mechatronics. It is a foundational course that assumes you have elementary or no prior knowledge of these subjects, but will require significant out-of-class time and effort. Most of the real work will happen outside of class, building in the workshops and programming, and interacting with your peers and the module tutors.

Gizmo is about creating things that work and understanding how to build them. You will not become expert engineers overnight but you will gain confidence in knowing which questions to ask when integrating hardware and software in an electro-mechanical system that interacts and controls the physical world.

Learning Outcomes

You will learn to design and build alpha prototype devices that integrate machine elements such as bearings, gears, cams and mechanisms with simple feedback control systems, in which a variety of sensors and actuators are connected to a microcontroller or single board computer.

Gizmo is not a distinct mechanics or electronics or programming course or, indeed, a design course. Gizmo aims to provide a broad overview of tools and techniques used in Physical Computing and Mechatronics, with particular emphasis on machine design processes. You will learn about three broad areas in this course:

- You will be introduced to the modelling, integration and best practices for use of machine elements such as bearings, gears, cams and mechanisms;
- You will be introduced to simple feedback control systems, consisting of actuators such as motors, sensors such as switches, basic electric circuits and microcontrollers or single board computers for comparing signals and driving actuators accordingly;
- You will be introduced to the rudimentary programming of microcontrollers or single board computers to affect a specific outcome, and how to interface the digital and physical world.

INTRODUCTION

Teaching Staff

Module Leader: Andrew Brand, andrew.brand@imperial.ac.uk

Tutors: Deborah Adkins, Shayan Sharifi, Aran Dasan
Jing Sheng Pang, Ariadna Blanca Romero
Peter Krige, Alex de Preez,
plus contributions from Prof Peter Childs

Communicating with you

For DE2, the principal means to communicate lecture, lab and coaching materials is Blackboard. DE2 students should refer to the information in Blackboard periodically to ensure updates are not missed. There will be a live FAQ section in Blackboard. Here any questions asked will be anonymized and answered to create a reference for the whole cohort.

For GID and IDE students, the principal means to communicate lecture, lab and coaching materials is Google Drive. Appropriate folders and files will be shared with you as the course unfolds.

Communicating with us

Outside of class, direct all correspondence to Andy unless otherwise invited by another member of the tutor team.

Group Assignment

You will learn by doing and through interaction with the module tutor team. This year in Gizmo, teams of 3 to 4 students will be challenged to weave design and technology to create an electro-mechanical machine that generates sound (it does not need to musical). The unifying theme this year is "**GizmoBand**". The group assignment constitutes all of the marks for Gizmo in the Autumn term (i.e. there are no exams or in-class assessments). Assessment criteria are fully described here.

Each team must design, build and demonstrate at least one machine that effectively integrates machine elements, sensors and actuators and software to perform a specified function. Your machine must work, but it does not need to fulfil a real-world need. It can be playful, joyful, whimsical, devious, large or small.

Your final machine does not need to work independently of mains power or your Laptop, i.e. the final piece may be 'tethered' by various wires and connected to your Laptop or to a bench power supply. On the final day of the module, you will share your creations, to be enjoyed collectively with tutors and your colleagues.

COURSE WORKLOAD – DE2

DE2 Students only

For DE2 students, Gizmo continues into the Spring term, when there will be greater emphasis on precision machine design, characterisation and analysis of machine elements though the application of mathematics and core mechanical engineering principles. For DE2 students, Gizmo constitutes 12 ECTS units and therefore 20% of your year.

Gizmo Course Workload, Autumn term (180 hours, 7.2 ECTS)

16 hours lectures; 8 hours labs ; 15 hours supported workshop time (IDEAs workshop); 12 hours project coaching and formal reviews; 14 hours self-study; **115 hours group assignment**

Course Workload, Spring term (120 hours, 4.8 ECTS)

8 hours lectures; 8 hours labs; 14 hours project coaching and formal reviews; 84 hours self-study and individual assignment

Assessment

Autumn term	**(20%) Group project report**
	(40%) Group project presentation
Spring term	(30%) Individual project report
	(10%) Individual project presentation

Breakdown of suggested effort in Autumn term (DE2 student)

Wk	Lecture	Lab	Support IDEAs	Self Study	Group work	Coach	Formal Reviews
1							
2	2 hrs	2 hrs		2 hrs			
3	2 hrs	2 hrs		2 hrs	10 hrs		
4	2 hrs	2 hrs	3 hrs	2 hrs	10 hrs		
5	2 hrs	2 hrs	3 hrs	2 hrs	10 hrs		
6	1 hr				10 hrs		3 hrs
7	2 hrs		3 hrs	2 hrs	15 hrs	2 hrs	
8	2 hrs		3 hrs	2 hrs	15 hrs	2 hrs	
9	2 hrs		3 hrs	2 hrs	15 hrs	2 hrs	
10	1 hr				15 hrs		3 hrs
11					10 hrs		

COURSE WORKLOAD – GID

GID Students Gizmo Course Workload, Autumn term

(equivalent to 125 hours, 5 ECTS)

7 hours live lectures; (7 optional lectures via video); 8 hours labs; 13 hours project coaching and formal reviews; 21 hours self-study; **64 hours group assignment**

Assessment

Formative only. Contributes to your body of work.

Timetable is subject to change. Refer to the GID1 or GID Visitors Google calendars as masters.

Suggested hours are a guideline only.

Breakdown of suggested effort in Autumn term (GID student)

Wk	Lecture	Lab	Support IDEAs	Self Study	Group work	Coach	Formal Reviews
1							
2	1 hrs	2 hrs		4 hrs			
3	1 hrs	2 hrs		4 hrs	8 hrs		
4	1 hrs	2 hrs		4 hrs	8 hrs		
5	1 hrs	2 hrs		4 hrs	8 hrs		
6	1 hrs				8 hrs		3 hrs
7	1 hrs			3 hrs	8 hrs	2 hrs	
8	1 hrs			3 hrs	8 hrs	2 hrs	
9	1 hrs			3 hrs	8 hrs	2 hrs	
10					8 hrs	1 hrs	3 hrs
11					8 hrs		

COURSE WORKLOAD – IDE1

IDE1 Students Gizmo Course Workload, Autumn term

(equivalent to 175 hours, 7 ECTS)

7 hours live lectures; (7 optional lectures via video); 12 hours labs; 25 hours project coaching and formal reviews; 18 hours self-study; **106 hours group assignment**

Assessment

Formative only. Contributes to your body of work.

Timetable is subject to change. Refer to the IDE1 Google calendars as master.

Suggested hours are a guideline only.

Breakdown of suggested effort in Autumn term (IDE1 student)

Wk	Lecture	Lab	Support IDEAs	Self Study	Group work	Coach	Formal Reviews
1							
2	1 hrs			3 hrs			
3	1 hrs			3 hrs			
4	1 hrs			3 hrs			
5	1 hrs			3 hrs			
6							
7	1 hrs	12 hrs		2 hrs	22 hrs	2 hrs	
8	1 hrs			2 hrs	32 hrs	2 hrs	3 hrs
9	1 hrs			2 hrs	32 hrs	2 hrs	3 hrs
10					20 hrs	1 hrs	3 hrs
11							

PRE-REQUISITES

You do not need any prior knowledge in mechanical or electronic engineering for this course. But some GID students may benefit from doing an introductory course to Python in parallel to Gizmo. If you have learned Python, Processing, C/C++, Javascript, or almost any other programming language, you will have sufficient knowledge to get going. For complete beginners, the tutor team will be on hand to assist. Complementary courses that go more in depth into human interaction design and computer programming will be available to IDE1/GID students in the Spring term. Complementary courses in programming and electronics run concurrently with Gizmo for DE2 students.

Similarly, students who have limited or no knowledge of 3D Computer Aided Design (CAD) software would benefit from doing an introductory course to SolidWorks or Fusion 360. As Imperial students, you can access e-learning courses for various software including SolidWorks and Fusion 360 via Lynda.com.

You will receive enough guidance about electronics to design and build your machines, but some students may benefit from reviewing basics on electronics, digital systems and various electric circuit components and electro-magnetic devices. For an introduction to these topics, go to the Electronics 101 section.

Python (recommended for GID students)

Learnpython.org (free)

Codecademy.com (free)

learnpythonthehardway.org (fee required)

SolidWorks (3D CAD)

You are eligible to download the Student Engineering Kit (SEK) 2016 version of SolidWorks for use on your own laptops.

Note that SolidWorks requires Windows OS.

Download SolidWorks 2016 from the Imperial software shop at softwarehub.imperial.ac.uk

If this link does not work, try registering for the download link.

Fusion 360 (3D CAD)

Students are eligible to use many Autodesk programs for free. Fusion 360 is a top-down 3D CAD modelling software that allows real-time remote collaboration. Download Fusion 360 from link. Fusion 360 runs on Mac or PC.

TEACHING FORMATS

Gizmo takes a hands-on approach, which means that you spend a lot of time sketch prototyping, building mechanisms, making and integrating machine elements and actuators, building basic circuits, soldering, and writing programs to affect a specified outcome. There are different touch points between course tutors and students to facilitate learning. The key teaching inputs are lectures, labs, coaching, and formal reviews.

Lectures – detailing essential information and knowledge to develop students' skills. Lectures are formal sessions that run alongside and inform the assignment. Lecture topics are timed and structured to support the needs of the assignment and address a wide range of topics from designing mechanisms to creating Internet of Things (IoT) devices. Each week, there will be in-class activities and problem sheets relating to the tools and techniques that have been introduced. These help the tutor team gauge the level of your understanding and how well we're doing in transmitting information

Labs – in-depth practical sessions on a particular topic. Labs are structured sessions, led by tutors and focus on a specific topic. These are interactive sessions, in which you'll be watching an instructor and then attempting to repeat what you have been shown. Attendance is essential. You will not be expected to submit work directly associated to the lab but non-attendance may mean you miss key information and an opportunity to build useful skills.

Project Coaching – scheduled time to work on group projects with guidance from module staff. Coaching sessions are a key source of tutor support and are compulsory. The main function of these sessions is project management and helping to resolve difficulties you have encountered. Tutors will be experienced in mechanical design, hardware integration, programming, 3D CAD sand manufacturing. Please think about what you want to get from each session in advance. You should seek focused advice and suggestions around particular challenges you face. There is no need to prepare presentation material for these sessions, but do arrive with questions, sketches, diagrams, parts, programs etc. Your tutor is an expert in their field, but may know little about your specific concept; aim to bring them up to speed quickly.

TEACHING FORMATS

Formal Reviews – scheduled time to show your work with feedback from module staff and students. Formal Reviews are presentations of your project work to a mixed audience of faculty members, visiting tutors and the student cohort. There are two Formal Reviews; the first is formative (i.e. it is not graded) and takes place at the end of the concept development phase. At this point, you will be expected to have achieved key milestones in the assignment and show the outputs described below. All teams must present. The tutors will seek clarification of your intentions by asking questions and give advice and feedback verbally. Whilst watching your peers present their work, you are encouraged to make notes and write down suggestions for things that have been done well and for things that will enhance their work. We shall ask you to submit these notes at the end of the session so do contribute professionally, using language and level of comments that you'd like to receive on your own work.

The second Formal Review takes place at the end of the realization phase of your assignment. This presentation takes the format of a concise description, demonstration and inspection of your final machine, and technical interview by a panel of faculty members and visiting tutors lasting approximately 15 minutes. You will receive verbal and written feedback on your presentation, including specific areas to reflect on for your report.

Conduct during Formal Reviews:

Students

- Arrive on time and do not wander in and out of the room during presentations.
- Be prepared – that means give a structured, practised presentation. Time is limited: each team will have up to 10 minutes to present plus up to 5 minutes for feedback, questions, and handover.
- Explain your work, visually and verbally; better still, demonstrate your work.
- Illustrate your process and direction.
- Listen to responses. Learn from responses.
- Defend, but don't be overly defensive.

Audience (including you, the students)

- Attend the whole of the Formal Review if possible and participate. Peer review is an important part of the learning process, and for your development of critical skills.
- Listen, question, probe, challenge.
- Provide positive and constructive feedback.
- Identify areas for improvement; offer variations, methods, references, different perspectives.

TEAM WORK

Team work is essential to the functioning of Gizmo and, indeed, any engineering endeavor and it is expected that students will work together in a safe, professional and collegial manner. Good communication skills and understanding group dynamics, team roles and management are invaluable assets for design engineers and takes effort so stick at it to turn your group into an effective team. During the first few weeks of the assignment, identify perceived problems within the group and deal with them promptly. Bring any perceived problems to the attention of Module Leader, who will happily help facilitate discussions between team members and, if necessary, make an intervention.

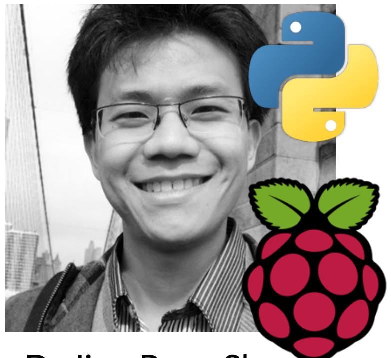
For DE2 students, an anonymous peer review will be conducted at the end of DRAW week and the results reviewed by the course staff. Grades, as an indicator of performance so far, will then be provided to each student along with individual, constructive feedback. Consider this a professional performance review – it does not define your final grade but can help with focus and direction if needed.

At the end of the course, team members will assess themselves and their team members using the WebPA online peer evaluation system. This self and peer assessment system is endorsed by and hosted at Imperial. For more information, refer to the Dyson School of Design Engineering Student Handbook (v5.5).

You will be asked to assess the contribution of each group member – including yourself. The Module Leader, in consultation with module tutors, will also assess individual contribution and effort. These assessments will be factored into your individual mark for the Gizmo group assignment, i.e. **DE2 students** will be marked partly on the achievement of the group and partly on that their individual achievement, as assessed by the individual themself, their team members and the Module Leader.

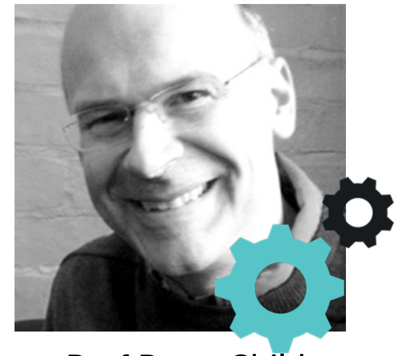
MEET THE TUTOR TEAM

Andy Brand
Module Leader

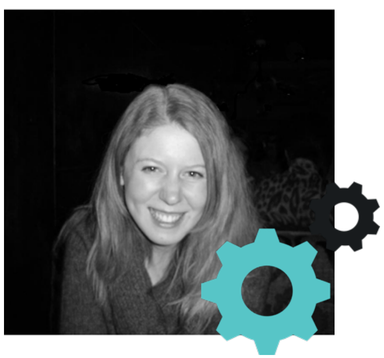


Dr Jing Pang Sheng
Python & RPi

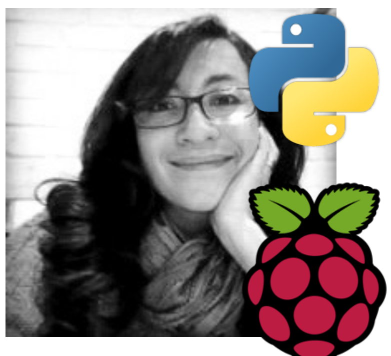
Peter Krige
Arduino & Mechatronics



Prof Peter Childs
Mechanical Engineering



Dr Deborah Adkins
Mechanical Engineering, IoT



Dr Adriana Blanca Romero
Python & RPi

Alex du Preez
Arduino & Mechatronics

Dr Shayan Sharifi
Mechanical Engineering, SolidWorks

MEET THE TUTOR TEAM

Andy Brand
Module Leader

Andy is Senior Teaching Fellow and Director of Postgraduate Studies in the Dyson School of Design Engineering, where he designs, manages, and teaches courses for Undergraduate & Postgraduate students. He is senior tutor for the Innovation Design Engineering (IDE) MA/MSc programme and now leads the first year together with Tim Corvin. His specialist interests lie in co-designing with adults and children with learning disabilities and neurological conditions, machine design and translating ideas into reality.

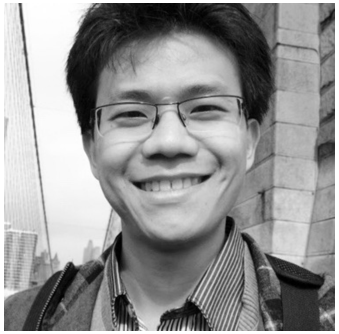
A few 'machines' that Andy has engineered: Mingo, Vesaro, Stellaris, Transit Wheels & Trim, TL90

Dr Deborah Adkins
Mechanical Engineering, IoT

Deborah is a Research Associate at the Dyson School of Design Engineering working on the HOUSE research project funded by the EPSRC. She specialises in energy efficiency in domestic buildings with a particular interest in the decision-making process surrounding retrofit.

Prior to joining Imperial Deborah was Lecturer in Building Physics and Course Director for the Architectural Environment Engineering degree at UNNC. Deborah used to live in an eco-house and she loves working on all things eco-tech.

MEET THE TUTOR TEAM



Dr Jing Pang Sheng
Python & RPi

Jing is Co Founder of Neuron Technology, a start-up that is developing community aided management systems for improving building efficiency. Jing is fascinated by the possibilities of new technology and products that can benefit our world and enjoys spending time exploring concepts and generating new ideas that may deliver a better quality of life. He has studied many different fields of science and engineering and holds a Masters in Physics and a PhD in Materials and Nanotechnology. Jing was recently appointed Strategic Coordinator for ICAH, where he is helping the organisation to grow as well as providing mentorship and technical advice to its members.

Dr Adriana Blanca Romero
Python & RPi

Ariadna is a highly motivated, enthusiastic Physicist, Data Scientist, and Developer with 8+ years of coding, data analysis and research experience. Her area of expertise is the atomistic simulation of materials in high-performance computing to understand its electronic structure. Ariadna is passionate about applying new technologies, machine learning, and data analytics to understand human behaviour, make strategic business decisions and develop products that help to improve people's lives.

Ariadna collaborates with researchers in Germany, USA, and Mexico. She has forged and nurtured a new network between research institutions in Germany and Mexico, providing access to knowledge, expertise, and scientific facilities to Mexican PhD students in cutting-edge labs.

MEET THE TUTOR TEAM

Peter Krige
Arduino & Mechatronics

Kudu is a London based design studio offering a bespoke service of industrial design and mechatronic consulting as well as custom hardware prototyping and development. Kudu was founded by Alex du Preez, a mechanical engineer, and Peter Krige, an electronics engineer. Kudu has built a reputation for developing new products from early concept to full scale manufacture in the UK and Asia. These include Beeline, Bento Lab, Hackaball and MOON.

Peter and Alex are graduates of the Innovation Design Engineering MA/MSc programme and have tutored on the course for several years. They will take the lead for IDE1 Gizmo, from 14th November. IDE1 are in safe hands!

Alex du Preez
Arduino & Mechatronics

MEET THE TUTOR TEAM

Prof Peter Childs
Mechanical Engineering

Peter is Head of the Dyson School of Design Engineering and the Professorial Lead in Engineering Design at Imperial College London. His general interests include: creativity; the application of creativity tools; mechanical and product design; robotics; rotating flow, temperature and its measurement, sustainable energy component, concept and system design. Peter is author of Mechanical Engineering Design Handbook, now in its 3rd edition. This book is one of the core texts for Gizmo. Peter and Andy have been working to distill parts of this book into more accessible formats for non-engineers; some of this material will be provided in Gizmo.

Dr Shayan Sharifi
Mechanical Engineering, SolidWorks

Shayan is a Teaching Fellow in the Dyson School of Design Engineering. He is also working on an industry sponsored project to design future devices for slurry transportation and mineral grinding. In his project and these particular devices, Shayan employs innovate solutions from the fields of Fluid Dynamics, Design Engineering, Materials Science, Manufacturing, Fracture Mechanics, Tribology, and Energy Efficiency. Prior to his current position, Shayan worked as a Research Associate at the University of Strathclyde's Department of Mechanical and Aerospace Engineering, following a PhD in the 'Tribology of Bio-Materials' (ceramics, polymers, metal substrates and coatings).

As a Research Associate, Shayan developed new approaches to improving the performance and durability of materials used in the power capture and conversion interface of tidal energy.

SYLLABUS – AUTUMN TERM

Wk	Start Date (Mon)	Monday	Tuesday	Wednesday	Thursday	Task & Assignment Milestone
1	03/10	No classes				
2	10/10		**Welcome** Course Introduction	*Lab 1: RPi set-up*	**Mechanics of Simple Machines**	• Primer/refresh electronics • Install SolidWorks/Fusion 360 • Begin reading course material
3	17/10		**Linkages 1**	*Lab 2: RPi GPIO, IoT*	**Linkages 2**	• Teams announced • Research, get inspired • Generate **concepts**
4	24/10		**Power Systems & Actuators 1**	*Lab 3: SolidWorks toolbox & motion analysis*	**Power Systems & Actuators 2** *Support in IDEAs lab (DE2)*	• Select concept; define independent functional requirements • Development thru synthesis • Sketch prototyping – mechanical
5	31/10		**Control Systems 1**	*Lab 4: Introduction to Pure Data*	**Control Systems 2** *Support in IDEAs lab (DE2)*	• Sketch prototyping – control • Explore capability of RPi / Arduino
6	07/11		**Making sounds (pm)** **Interim Review (DE2)**	**Interim Review** (GID)	**Interim Review** (DE2)	(DE2 & GID) At the **interim review** show: • Layout configuration and sketch models of **single concept** • Bench level control system • Parts identified or designed to a conceptual level
7	14/11	*Arduino workshop (IDE1)*	**Transmissions 1** *Arduino workshop (IDE1)*	*Project Coaching (DE2, GID)*	**Transmissions 2** *Support in IDEAs lab (DE2)* *Project Coaching (IDE1)*	Engineering analysis, simulation, detail design, iterative development through prototyping, acquiring parts, fabrication, integration, assembly and testing (**debug, test again**), document
8	21/11	**Interim Review 1** (IDE1)	**Transmissions 3** Project Coaching (IDE1)	*Project Coaching (DE2, GID)*	**Transmissions 4** *Support in IDEAs lab (DE2)* *Project Coaching (IDE1)*	
9	28/11	**Interim Review 2** (IDE1)	**Connections 1** *Project Coaching (IDE1)*	*Project Coaching (DE2, GID)*	**Control Systems 3** *Support in IDEAs lab (DE2)* *Project Coaching (IDE1)*	
10	05/12		**Final Review** (GID)	**Final Review** (DE2) **Final Review** (IDE1)		**Demonstration & presentation** Refer to 'Assessment – Formal Review'
11	12/12					**Report submission** Refer to 'Assessment – Report'

WORKFLOW

Teams should adopt a deterministic approach, in which uncertainties are dealt with by using conservative values, safety factors and best practices ("rules of thumb") and through iterative development through synthesis, simulation, analysis and **physical prototyping**. In general, the number of iterations is directly related to quality of the final design.

Synthesis is the process of combining ideas, referring to analogous systems and making estimations to arrive at potential solutions. Analysis involves the application of engineering science to determine quantitative information, geometry and detail design. Analysis and synthesis invariably go together, but you will have to synthesise your Gizmo device before you analyse it.

In Gizmo, **fixing a concept early** on and allowing plenty of time for iteration will give scope for greater level of creativity and invention. The joy and learning in this module is in the development of your machine, not in the initial enquiry. Your research should be about getting inspired (generate moodboards, Pinterest pages, whatever works for you) and looking at prior art. The world is full of clever mechanisms and machines and you can start with a mechanical system that intrigues you as an alternative to starting with a specific method for generating sound.

Tips

- Consider the loads that will need to be overcome and the orientation and speeds (motion) of effort first; i.e. define the mechanics first and then the electrical, electronic parts.
- Once you have a concept, decompose the system into basic, independent functions and keep them separate throughout development, whilst keeping an eye on how the solutions will integrate successfully.
- Create Gizmo devices that are explicitly simple. Start with the simplest principle and add complexity as needed.
- Build prototypes – virtual and physical. Don't overlook the usefulness of paper, tape, cardboard, glue as prototyping materials. Acquire parts instead of making parts when possible.
- Good mechanical design is often more about using good practices (based on fundamental engineering principles) and inventiveness than detailed analysis.
- Move quickly but resist the tendency to become too detailed too quickly.
- Design for manufacture and assembly, which means designing for the constraints you face (time, resource, access to materials and equipment)
- Refer to the assignment milestones in this table and plan accordingly

WORKFLOW

Potential starting points

Groups are not limited to one of the four starting points below. These are merely suggestions to get you going. You may equally get inspired by a particular illustration, musical instrument, mechanism, motion or by hacking and repurposing a found machine. Inspiration can come from anywhere:

- Motor driven mechanism to control the motion of a sound generating object, e.g. a device that controls the position and onset of a baton to a xylophone
- Electro-mechanical (physical) sonification of a piece of music or sound, e.g. a device that translates MIDI into mechanically generated sound or a kinetic performance
- Electro-mechanical (physical) sonification of a dataset, e.g. a device that translates weather data into mechanically generated sound
- Mechanical trigger of electronic sound maker, e.g. a device that constitutes cams and linkages to strike a piezo sensor, which in turn triggers a drum machine

ASSESSMENT – FORMAL REVIEW

For the group project, each team must demonstrate at least **one working physical machine** that effectively integrates machine elements, sensors and actuators and software to perform a specified function. You should demonstrate working prototypes live in the final Formal Review. If a live demonstration is not possible, then you may show a video. In fact, everyone should have video of their Gizmo working as a back up, ready to show at the Formal Review in case the machine does not work. In addition to the demonstration, you may show sketches, prototypes, analyses, and video content. There is no specific ground plan for your presentation, but a plan should exist. Not all team members need to present. **You will have up to 10 minutes to present your machine followed by feedback and questions from the review panel.** Be prepared to answer technical questions. Mark /20

Assessment Criterion	Gizmo works as intended	Inventiveness and Creativity	Optimisation (focus on 2 features)	Oral Presentation and Questions	Visual presentation of machine
4 - Exceeds expectations	All functional objectives fulfilled – it works! Successful integration of machine elements, actuator(s), sensor(s), & control	Inventive and creative thinking is clearly evident – both in approach and embodiment	Final machine developed though full and appropriate evaluation (focus on 2 features)	Content balanced and professional, students audible, good use of props/ slides. Questions handled expertly	Visually engaging, appropriate use of manufacturing techniques & materials. Well finished
3 - Secure (Meets expectations)	Functional objectives are addressed but are incomplete or missing some elements – it almost worked!	Some inventive and creative thinking is evident both in approach and embodiment	Final machine developed though partial and appropriate evaluation (perhaps missing some analysis)	Content balanced and professional, students audible, good use of props/ slides. Students have some difficulty answering questions	Visually engaging, mostly appropriate use of manufacturing techniques & materials. Well finished
2 - Developing (approaches expectations)	Functional objectives are inadequately described or poorly translated – it could have worked.	Students show creativity in approach, but use standard solutions	Some evidence of evaluation but mostly inappropriate	Audible, good use of props/slides. Students have significant difficulty answering questions	Mostly appropriate use of manufacturing techniques, roughly finish
1 - Beginning	Functional objectives have not been considered – it was never going work.	Students show little creativity in approach or in embodiment of machine	Little evidence of iteration, synthesis, analysis, or evaluation	Inaudible, poor use of props/slides. Students have significant difficulty answering questions	Inappropriate use of manufacturing techniques, poorly finished

ASSESSMENT – REPORT

The report should complement your presentation at the Final Review. It is a record of the development process that documents the journey from concept to final embodied, working machine. This means you must keep notes, sketches, hand calculations etc., and photograph of prototypes throughout the term. You can capture this data in a physical Logbook or Blog.

An electronic copy of the report should be submitted via Blackboard in the final week of the module, which will be checked for plagiarism. You need only submit one report per group.

The final report should be A4 (landscape of portrait) and not more than **20 pages long**, including **everything** that you submit (i.e. summary, main body, contribution statement and appendices). Use the report to describe your inspiration, key decisions that were made, how ideas were combined and developed (synthesis), application of core mechanical and electronic engineering (analysis), evidence of iteration and refinement (optimisation). You do not need to include technical drawings for the Group assignment.

Keep it visual, use tabulated data, annotated diagrams and photographs where possible.

Gizmo projects differ widely in nature and scope and this will be reflected in the structure and contents of your report. You should discuss your report with the Module Leader if you are in doubt. The report might include:

- Summary
- Table of contents
- Nomenclature and abbreviations
- Introduction, inspiration and aims
- Statement of roles and main contributions by each member of the group
- Materials and methods (this section of the report might include, for example, research, ideation, prototyping, simulation, analysis, risk assessment, iterative development, manufacturing plan)
- Reflection (what went well; what could be improved?)

The final report should include a full description of the final machine, including:

1. Weblink to a video of the final machine working
2. Annotated photograph(s) of the final machine
3. Copy of any code (weblink to Github is acceptable)

ASSESSMENT – REPORT

The final report should be A4 (landscape of portrait) and not more than **20 pages long**, including **everything** that you submit (i.e. summary, main body, contribution statement and appendices).

Submit **one report per group**. Don't forget to include your individual contribution statements (i.e. statement of roles and main contributions by each member of the group) and weblinks to video and code as appropriate.

Mark /20

Assessment Criterion	Summary and description of methods	Inventiveness and Creativity	Optimisation (focus on 2 features)	Description of final machine (inc. code)	Structured and visual presentation of report
4 - Exceeds expectations	Comprehensive and concise description of research, iterative development, risk assessment. Publishable	Inventive and creative thinking is clearly evident – both in approach and embodiment	Final machine developed though full and appropriate evaluation (fully documented for 2 features)	High quality video, clearly annotated images, appropriate terms used in labels, accessible code	Organised, professional, high quality English, highly visually engaging
3 - Secure (Meets expectations)	Concise description of research, iterative development, risk assessment with some omissions	Some inventive and creative thinking is evident both in approach and embodiment	Final machine developed though partial and appropriate evaluation (perhaps missing some analysis)	Good quality video, clearly annotated images and accessible code but some terms used incorrectly	Organised, professional, good quality English, visually engaging
2 - Developing (approaches expectations)	Description of research, iterative development, risk assessment with several omissions	Students show creativity in approach, but use standard solutions	Some evidence of evaluation but mostly inappropriate	Low quality video, annotated images, code difficult to follow	Disorganised, but good quality English, visually engaging
1 - Beginning	Little evidence of research, iterative development, risk assessment, planning	Students show little creativity in approach or in embodiment of machine	Little evidence of iteration, synthesis, analysis, or evaluation	Poor quality video, poorly annotated images, inaccessible code	Disorganised, unprofessional, poor use of English

HEALTH & SAFETY

Risk Assessment

Naturally, your project work is ambitious and daring and, in Gizmo, you will likely conduct some activities that pose a risk to your safety and the safety of others. Please read this chart. If you answer "yes" to any of the questions in the flow diagram:

1. Desists from doing the potentially harmful activity.
2. Go to appropriate documents via the embedded links and read Draft a Risk Assessment (fill in what you can) and contact the Module Leader.
3. Await the Module Leader's permission to continue. You may need to put in place control procedures and modify your planned activities.

Normal workshop activities such as using the machine equipment and tools do not required a risk assessment, if you have successfully completed induction training for that particular workshop and demonstrated competence.

These processes are about enabling you to conduct the exciting work that you want to do, without harming yourself or those around you. So dream big, but always assess the risks are involved. As safe, ethical and professional designers and engineers, it is not acceptable for you to ignore this process.

COSHH forms

The workshops have material data sheets for most standard materials. For any hazardous substance used in your project, a COSHH (Control Of Substances Hazardous or Harmful to Health) form must be completed. Suppliers of materials are obliged to provide you with a data sheet, which explains any handling or contact hazards, and defines any necessary precautions. Ensure you have submitted COSSH forms to the appropriate Safety Officers before acquiring the substances. In the IDEAs workshop, the safety officer is Ingrid Logan.

EQUIPMENT & MATERIALS

You will be building a lot in this course, both electronic and mechanical devices, so you will need certain equipment, parts and materials. If you've done any mechanical, electronics or microcontroller project development, you may have enough parts to get going already

DE2 and GID students will be working with the Raspberry Pi platform and programming in Python. Each group of four students will be given a Raspberry Pi 3, power adaptor and MicroSD card with installation image at the beginning of the module. The RPi labs were written using this board, but should also work for the Pi Zero or Model A+ (in combination with WiFi dongle), which are more useful for embedded projects, and projects which require very low power. You may chose any variant from the Raspberry Pi platform, as long as it works, but if use a model that your tutor has never seen, help may be limited.

There are a lot of choices when it comes to platforms on which to build and prototype physical computing systems. Lately, microcontroller development boards such as Arduino have been a popular choice because they have become very easy to work with. But system on a chip platforms like the Raspberry Pi are a lot different than traditional microcontrollers in many ways.

In fact, the Raspberry Pi has more in common with your computer than it does with an Arduino. This is not to say that a Raspberry Pi is better than a traditional microcontroller; it's just different. For instance, if you want to make a basic feedback control system that comprises a sensor and actuator (e.g. temperature controlled motor), it is better to use a microcontroller such as the Arduino Uno for purposes of simplicity. But if you want to remotely access the system via the Web to change its settings and download data log files, you should consider using a Raspberry Pi.

A microcontroller should suffice most Gizmo devices. But DE2 and GID students will use Raspberry Pi and Python as they will be required to use these platforms later in their courses.

IDE students will be working with Arduino. Students will be issued with Arduino Uno and Mega boards. Arduino is an open source hardware and software platform and very active community of enthusiasts. Whatever you want to do in Gizmo (in terms of control) has most likely been done before with Arduino and someone will have posted the solution online. Arduino offers a low-barrier-to-entry, but very capable prototyping platform for physical computing and mechatronics.

EQUIPMENT & MATERIALS

If you've never done any physical computing or mechatronics work before, you might want to get a starter kit (you can get similar kits to this, but without the microcontroller board or buy the individual components, available from several providers).

We shall provide some electronics components such as resistors, capacitors, LEDs, cables, bread boards as well as equipment like soldering irons, bench power supply units, multimeters and oscilloscopes in the **mechatronic space in the IDEAs lab** (Skempton 238). Please don't hoard parts and equipment; take what you need, return what you don't use. You will be responsible for sourcing other kit.

You can use **consumables** (adhesives, tapes, fasteners) and **materials** in the IDEAs workshop. Please check with Technicians that material has not been reserved for another job. You can also withdraw stock materials from Mech Eng stores via Ingrid Logan. You will need permission from the Module Leader for each withdrawl from Mech Eng (signature or email). You may assemble metal parts in the IDEAs workshop, but there should be **no metal working** in there (cutting, drilling, fabricating). Use the Student Teaching Workshop or RCA Darwin workshop as appropriate.

Most of the hand tools that you will need are available from the IDEAs workshop (you can check-out a **tool kit**; simply ask a Technician), but it would be helpful to have your own basic tool kit. Items you may need: screw driver and bit set, miniature Pozi/Phillips/Flat screw driver, needle nose pliers, wire stripper, diagonal cutter, craft knife, steel rule.

Most basic **power tools**; (drills, jigsaws, dremmels, oscillating multi-tools etc.) are available from the IDEAs workshop. Students may not use their own power tools in the IDEAs workshop.

Storage space in the IDEAs workshop is limited. You may store your Gizmo parts / device in one of the transparent storage boxes – strictly one box per group.

Personal protective equipment must be worn in the Student Teaching Workshop and IDEAs workshop. You must wear a protective overall (boiler suit or laboratory coat) and safety glasses at all times. You must wear shoes that enclose your entire feet and that are considered to be robust. Boots, shoes or trainers are acceptable, provided they are considered suitably durable

DEFINITIONS

Mechanisms are systems of parts or features that transmit forces, motion and energy in a predetermined manner

Machine is an assemblage of mechanisms

Simple Machine is an elementary mechanism with no moving features - lever, wheel & axle, pulley, inclined plane, wedge and the screw

Electronics is a branch of engineering concerned with the design of circuits or devices that use transistors and microchips

Physical Computing is an approach and creative framework to human-machine interaction (HMI) design that starts by considering how humans express themselves physically. It takes the human body and its capabilities as the starting point and attempts to design interfaces, both software and hardware, that can affect outcomes in the physical world.

Mechatronics is a multidisciplinary field that combines - and aims to unify - mechanical engineering, electronics, computer engineering, telecommunications engineering, systems engineering and control engineering. Mechatronics is an approach to automation and, in the case of robotics, autonomous systems. Many of the tools and methods that are used in mechatronics are common with physical computing but the two terms can be used distinctly to describe very different approaches – the former aims to work in the absence of people and the latter in response to and between people.

RESOURCES

Core texts (copies available from Imperial library)

Childs, PRN. (2013)	*Mechanical design*. 3rd edition, Elsevier Butterworth Heinemann.
Horowitz , P. (2015)	*The Art of Electronics*, 3rd edition. Cambridge University Press

Useful texts

Branwyn, G. (2003) q	*Absolute Beginners Guide to Building Robots*. 1st edition, QUE
Igoe, T. (2011)	*Making Things Talk: Using Sensors, Networks, and Arduino to See, Hear, and Feel Your World: Physical Methods for Connecting Physical Objects*. 2nd edition. O'Reilly
Nussey, J. (2013)	*Arduino For Dummies*. Wiley
Reas, C. (2010)	*Getting Started with Processing: A Hands-on Introduction to Making Interactive Graphics*. O'Reilly
Richarson, M. (2014)	*Make: Getting Started with Raspberry Pi*. 2nd edition, Makermedia
Tilden, M. (2002)	*JunkBots, Bugbots, and Bots on Wheels*. 1st edition, McGraw-Hill Osborne

RESOURCES

Inspiration – Theme specific

MechBass, Wintergatan, Marble Machine, Pat Metheny – Orchestrion, BAM BAM the OBEN, xoxx composer, Alex Allmont's playhouse, Electric Knife Orchestra, sound machines by Dmitry Morozov

Inspiration – General

Imperial College Robotics	Imperial College has extensive robotics activity including mechatronics systems design and control, autonomous systems and artificial intelligence, medical and rehabilitation robotics, computer vision, neuromechanics and social robotics
1700 Mechanisms Transmissions	Nguyen Duc Thang is an engineer who has been working on an amazing, animated 3D catalogue of mechanisms since he retired in 2002. Very generously he shares all his work
1700 Mechanisms Transmissions 2	
1700 Mechanisms Specific Purposes	
www.creativeapplications.net	Highly curated selection of creative use of technology
Festo Bionics Learning Network	Festo has been developing Bionic robots since the 1990s. Check out the projects from the last decade.

UK based studios

Troika

United Visual Artists

Random International

Jason Bruges Studio

Moritz Waldemeyer

Cinimod Studio

RESOURCES

Knowledge bases

Arduino	The Arduino playground is a great place to start to learn the basics and find out how to hook up sensors, displays and actuators, etc.
Raspberry Pi	Home of the Raspberry Pi Foundation. Lots of information about RPi products and tutorials.
Code Academy	Online, free learning resource for learning programming
Make	Plenty of how-to's related to Arduino, Raspberry Pi, prototype making, etc.
Sparkfun	Excellent resource: basic introductions, component buying guides, soldering tutorials - it's all here.
Adafruit	Fantastic tutorials to get you started with electronics prototyping.
IDE Wiki	Physical computing toolkit compiled for an IDE Gizmo-esque module in 2012. Contains advice, code and diagrams for numerous Arduino how-to's including more advanced applications such as PS3 Eye or Emotiv Neuroheadset
Processing	For those projects that need a little more computer power, visualisations or audio
Instructables	The bible of DIY walkthroughs.
LetsMakeRobots	How to make your first robot, a whole community of DIY enthusiasts.
Solarbotics	Minimal robots
Hackaday	A community of hardcore electronics and software hackers contribute useful tips.

RESOURCES

Components and Materials	
Services (based in London)	
RapidForm	RCA rapid manufacturing facility
Digits2Widgets	Competitively priced rapid manufacturing in London
Cut Laser Cut	Laser cutting. Great service
Hamar Arcylic	Laser cutting. Grumpy but quick service
CNC Workshop	CNC cutting (wood). Quick service
Craft materials	
4D Modelshop	Wide range of modeling materials and tools
London Graphics	General art & design materials
Cass Art	General art & design materials
Moss & Co	Wide range of timbers
Packaging 2Buy	Cardboard
Direct Plastics	Plastics
Bayplastics	Plastics. Excellent online and mail service
Robotics and CNC parts	
Technobots	Reasonably priced supplier of robotic elements, mechanical components and electronics.
ActiveRobots	An excellent resource for robot kits, and component parts & motors.
WorldofCNC	Provider of industrial quality CNC components, frames, transmission, motors, control, etc.
MotionControlProducts	A great selection of powerful servo motors and controllers, linear actuators, encoders, etc.
4QD	Sell all sorts of motor controllers, etc, also a very useful resource to learn about automation, etc.

RESOURCES

Components and Materials

Electronics suppliers

Maplin	Basic electronics. Lots of high street outlets in London and online catalogue.
Farnell	Huge electronics component range, free next day delivery guaranteed – can be pricey but very useful.
RS	The other electronics behemoth **- also suppliers mechanical components and motors, materials,** etc.
Mouser	Reliable and quick. Stock RPi and Arduino compatible kit
CoolComponents	UK distributer for Sparkfun, Arduino, Olimex electronics devices.
SparkFun	A very useful resource for high quality hacking and prototyping devices. Highly recommended.
RobotElectronics	Sensors, motors, controllers, lots of variety, UK based

Mechanical component suppliers

HPCGears	Gears and power transmission.
SpringMasters	Springs, clips, washers and plenty of other hardware.
S3I	Steel wire, fixings, lanyards, brackets, etc.
EMA-Models	Model making material supplier.
Mindsets	Teaching supplier resource, full of wacky and useful materials for prototyping.
ModelFixings	Poorly made website, but a great range of mechanical fixings.
OnlineBearings	Bearings and power transmission products.
BearingBoys	Plenty of mechanical components, materials, motors, etc.
SimplyBearings	Specialise in bearings, wide variety: miniature, loose, bushings, etc.
OnDrives	Mechanical drive components, specialise in fixed reduction gearboxes and precision gears.
ChainReactionCycles	Bicycle parts, but can be useful for finding high quality mechanical components.
CrossMorse	Power transmission components
SDP-SI	Massive range, USA delivery only, but great for finding 3D CAD models of parts.

ELECTRONICS 101

In order to understand how electronic circuits work, and how to use them to build your Gizmo devices, there are some basic terms, relationships, and components that you need to know about. There is simply not time in the Gizmo schedule to cover these topics and many of you will be familiar with them already. For revision on electronics, check out these resources:

DE1 Introduction to Electronics - read / watch lectures 1, 2, 7, 17 & 20 (videos require Panopto). Don't worry about maths.

A few definitions

Electricity is the flow of electrical energy through conductive materials. An electrical circuit is made up of two elements: a power source and components that convert the electrical energy into other forms of energy. We build electrical circuits to do work, or to sense activity in the physical world.

Sensors are components that convert other forms of energy into electrical energy so we can read the changes in those other forms. Switches, knobs, light and motion sensors all fit in this category. Actuators are components that convert electrical energy into other forms. Light bulbs, motors, LEDs, and heaters are all actuators.

Electronics refers to reading changes in electrical properties as information. For example, a microphone changes sound pressure waves in the air to a changing electrical voltage. This process of changing one energy into another is called transduction, and devices that do it are called transducers. Much of the technical work of physical computing is about figuring out what forms of energy a person is generating, and what kind of transducer you can buy or build to read that energy. In order to do that, though, it's necessary to understand a few things about electricity.

Voltage is a measure of the difference in electrical potential energy between two points in a circuit. It is measured in Volts.

Current is a measure of the magnitude of the flow of electrons through a particular point in a circuit. It is measured in Amperes, or Amps.

Resistance is a measure of a material's ability to oppose the flow of electricity. It is measured in Ohms.

There are two common kinds of circuits: **Direct Current** (DC), and **Alternating Current** (AC). In a DC circuit, current always flows one direction. In an AC circuit, the direction of current flow is reversed in a regular repeating cycle. Most of the circuits you will use in Gizmo will be DC circuits.

Schematic diagram are diagrams of circuits that represent the electrical relationship between the components in the circuit. This is a helpful video on the topic.