St Mary's University
Twickenham
London

APH6010

3D Manufacturing

Semester 2 (option module – 20 credits)

2016 - 2017

School of Sport, Health and Applied Science

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Contents

Module Aims

The module is divided into three sections:

- **Additive Manufacturing Processes and Techniques :**
  - To understand the differences between subtractive (conventional) and additive manufacturing[1] (AM), the breadth of applications (e.g. archeological, medical and architectural), techniques and materials available for AM processes.
  - To understand the general AM process (CAD 3D Model → Slicing → G code).
  - To describe techniques for model surface reconstruction

- **Physics of Additive Manufacturing :**
  - To introduce the relevant material physics, understand the extrusion process in more detail and factors involved in the limitations of the AM printing.
  - To describe polymer physics and its use in laser-based AM techniques (e.g. stereolithography)

- **Practical design skills and applications :**
  - To develop practical design and printing skills

These areas will be labelled as 'Techniques', 'Physics', and 'Design Skills' respectively in the rest of this document.

[1] Here we use the term additive manufacturing as a synonym for 3D printing

Learning Outcomes

By the end of the Module, in terms of **knowledge** students will be able to:

a. Describe additive manufacturing processes, their physical basis, benefits and limitations
b. Describe the generalised AM design process
c. Use computer-aided manufacturing and slicing software programs to print 3D parts using a Fused Deposition Modelling (FDM) system
d. To understand the physics of materials within the context of AM

By the end of the Module, in terms of **skills** students will be able to:

f. Apply theory to practical concepts, including in increasingly unfamiliar contexts.
g. Demonstrate confidence and flexibility in identifying, defining and evaluating complex problems.
h. Demonstrate the ability to work with ideas at a level of abstraction in terms of conceptualisation and critical thinking
i. Reflect critically and make judgements in light of evidence and argument;
j. Engage in analytical and evaluative thinking.
k. Extract and synthesise key information from a variety of sources.

Your Responsibility

It is important for your success on the module that you make every attempt to attend all the sessions, and therefore attendance is an expectation, and registers will be taken. If you cannot attend please inform the module convenor or programme administrator by 9am on the morning of the session (leave a phone message, or send an e-mail), and explain why you will be absent. If you are having problems that make attendance difficult for you, then please seek advice.

You should check MyModules and your St Mary's e-mail on a regular basis (at least twice a week, more often is preferable) to ensure that you have the latest information. Making the checks is your responsibility; we can put the information out there, but you have to do your part by reading it!

You are responsible for your own learning experience. The module is a single module and runs over 11 weeks in semester 2. Class contact will consist of two 2hr sessions per week (4 hours in total). Approximately 10 hours per week of private study is expected in addition to class contact. Students are expected to do a significant amount of background reading and note-taking outside of timetabled sessions. **Take the initiative - do not expect to be spoon-fed everything you need to know**!

If you are getting lost, confused, or struggling in any way, then please seek help sooner rather than later; we promise to listen, and if possible, to do what we can to help you sort out any problems, even if the problems are entirely of your own making, but for us to help you, you have to let us know that you need help.

Teaching/Learning Strategy

The module is a single-module and runs over one semester only. Class contact will consist of two 2hr sessions per week, comprising lectures, workshops, tutorials and time allocated for project work.

Lectures

Each topic is introduced in the lecture. In general each individual lecture will cover one or two main areas and aims to support the acquisition of knowledge by providing a structured framework for further study. **You are expected to make your own notes during the lecture. You should work on your note-taking skills to ensure that you develop a technique which works for you**. You should try to read relevant chapters of your text book before the lecture. After the lecture, ensure your notes are organised and comprehensible, and supplement them with further reading. These will be a valuable resource when the time comes to revise for the exam.

Tutorials and Problem Sets

The weekly tutorials have more scope for discussion focused on relevant problem sets. Problems sets will be issued for completion outside of class, to be completed before the next tutorial. They focus on critical analysis and solution of numerical problems and discussion of theoretical topics, and the development of problem-solving and critical/analytical thinking skills. Tutorials provide an active learning environment in which students can develop their analytical skills through group work, discussion, and examination of the structure of problem solving.

Workshops and Worksheets

The weekly workshop slots are a key component of the course and will be used to enable taught practical work. Worksheets will be used in class to guide the learning.

Resources

Core texts

Due to the exciting and evolving nature of additive manufacturing, the module utilises a number of online and accessible review papers alongside recent texts. Please request pdf copies of review papers from the module convenor if you are unable to find them. Most of the textbooks are available in St Mary's University; however, you are welcome to purchase your own textbooks:

Online

OpenSCAD manual
https://en.wikibooks.org/wiki/OpenSCAD_User_Manual

OpenSCAD cheatsheet – an overview of available commands
http://www.openscad.org/cheatsheet/

Textbooks

1) Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, I. Gibson, D. Rosen, and B. Stucker. Springer New York. (2015).

2) Functional Design for 3D Printing (2nd Edition): Designing 3D printed things for everyday use, C. T. Smyth. CreateSpace Independent Publishing Platform. (2015)

3) Mathematics for Computer Graphics (4th edition), J. Vince. Springer. (2014)

4) General Physics : Mechanics and Molecular Physics, L. D. Landau, A. I. Akhiezer, and E. M. Lifshitz. Pergamon. (1967).
5) Fabricated (1st Edition), H. Lipson and M. Kurman, Wiley. (2013)

6) Computer Vision, D.H. Ballard and C.M. Brown, Prentice Hall. Available at http://homepages.inf.ed.ac.uk/rbf/BOOKS/BANDB/bandb.htm

7) Three-Dimensional Computer Vision, Y. Shirai, Springer-Verlag (1987).

Accessible review papers

1) Fundamentals of Stereolithography, P. F. Jacobs, 196-211, July 1992.

2) A review of melt extrusion additive manufacturing processess: 1 Process design and modelling, B. N. Turner, R. Strong, and S. A. Gold, 192-204, Rapid Prototyping Journal, July 1992.

Additional Texts

In order to understand the mathematical background, a number of additional texts can be consulted including:

- Polygon Mesh Processing, M. Botsch, L. Kobbelt, M. Pauly, P. Alliez, and B. Levy (2010).
- Mathematical Methods in the Physical Sciences (3rd Ed). M.L. Boas, Wiley, (2006).

This is not a definitive or comprehensive list. There are many useful and interesting texts available, ranging from introductory outlines to advanced texts. You should make a point of checking what is available in both the library and book shops, and following referenced papers through to alternative sources.

Journals

Rapid Prototyping Journal
Nature
Science

Electronic Resource
The majority of Physics and Mathematical journals are available via Web of Knowledge, EBSCO, Scopus.

These are available only through the SIMMSpace. Go to the ‘Library/IT’ tab at the top of the screen. Then click on ‘Find Library Resources’, then ‘Journals and e-resources’ at the bottom of the page. You will see a link under the ‘Popular E-resources databases’.

Course Materials

The module is supported by PowerPoint handouts which contain outline materials for each topic and podcasts. These materials are not intended to be comprehensive, and are definitely not a substitute for text books and journals. They are to be used in conjunction with your own lecture notes and further reading.

All materials will be posted on ‘MyModules’. **One of your priorities during the semester should be that you check ‘MyModules’ regularly.**

Lecture and Tutorial Programme

Module timetable

Worksheets to be completed in class.
Problem set due a week Friday after it is set (can be completed in class time if available).

Date	**Session 1** **(10.00-12.00 ; NPL)**	**Session 2** **(14.00-16.00 ; NPL)**
Friday 3/2/17 **Week 24**	Lecture 1: Introduction to 3D Additive Manufacturing	Lecture 2: The General AM Printing Process Lecture 3: Polymer Physics Problem Set 1
Friday **10/2/17** **Week 25**	Workshop: Design Techniques I Worksheet 1	Lecture 4: Stereolithography I Tutorial 1
Friday **17/2/17** **Week 26**	Workshop: Design Techniques II Worksheet 2	Lecture 5: Stereolithography II Problem Set 2
Friday **24/2/17** **Week 27**	Workshop: Design Techniques III Worksheet 3	Lecture 6: Applications of Lithography I Tutorial 2
Break – Week 28		
Friday **10/3/17** **Week 29**	Workshop: Design Techniques IV Worksheet 4	Lecture 7: Applications of Lithography II Problem Set 3
Friday **17/3/17** **Week 30**	Lecture 8: Materials Physics for AM Techniques I	Lecture 9: Materials Physics for AM Techniques II Tutorial 3
Friday **24/3/17** **Week 31**	Lecture 10: Fused Deposition Modelling I : Overview	Lecture 11: Fused Deposition Modelling II : Further physics of FDM Problem Set 4 **** Project specification will be provided for coursework ****
Friday **31/3/17** **Week 32**	Project Week 1	Lecture 12: Alternative AM techniques Tutorial 4
Friday		Lecture 13: 3D Metrology and

7/4/17 **Week 33**	Project Week 2	Surface Reconstruction I : Techniques
Break – weeks 34 and 35		
Friday **28/4/17** **Week 36**	Project Week 3	Lecture 14: 3D Metrology and Surface Reconstruction II : Data processing techniques and algorithms Problem Set 5
Friday **5/5/17** **Week 37**	Project Week 4	Lecture 15: Course summary – example worked questions Tutorial 5 *** *Hand in project report (coursework)* ***

Lecture 1

Introduction to 3D Additive Manufacturing

Lecture Aims

- To understand the differences between conventional (subtractive) and additive manufacturing
- To consider the use of 3D manufacturing for Physics

Content

- Why 3D manufacturing and applied Physics course?
- Historical perspective on manufacturing physics
- Overview of 3DM physics areas
- The modern product supply chain

Core Reading

- Chapter 1 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.
- Chapter 1-4 : Fabricated (1st Edition), H. Lipson and M. Kurman, Wiley. (2013).

Lecture 2

The general AM Printing Process

Lecture Aims

- To understand the general 3D printing process
- To understand the taxonomy of 3D manufacturing systems into liquid, particulate, and solid sheet binding techniques

Content

- The generalised 3D printing process (CAD → Slicer → G code)
- The five main manufacturing processes: curing, sheet, dispensing, sintering, and binding.

Core Reading

- Chapters 1, 3, and 13 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

- Chapter 5-6 : Fabricated (1st Edition), H. Lipson and M. Kurman, Wiley. (2013).

Lecture 3

Polymer Physics

Lecture Aims

- To understand polymers and their properties as materials used within AM

Content

- Polymer structures, properties and their use in AM
- Cross-linking and polymerisation

Core Reading

- Chapter 4 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 4

Stereolithography I

Lecture Aims

- To describe and understand Stereolithography (SL) and relevant Physics

Content

- Description of the Stereolithography process
- The modelling of SL (Beer-lambert law applied to laser-induced UV polymerisation)

Core Reading

- Fundamentals of Stereolithography, P. F. Jacobs, 196-211, July 1992.

- Chapter 4 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 5

Stereolithography II

Lecture Aims

- To describe and understand Stereolithography (SL) performance

Content

- AM Performance Calculations : Cure depth and shape, line width and resolution

Core Reading

- Fundamentals of Stereolithography, P. F. Jacobs, 196-211, July 1992.

- Chapter 4 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 6

Applications of Lithography I

Lecture Aims

- To introduce two-photon polymerisation and its lithographic applications

Content

- Two-photon polymerisation (2PP) build system introduction
- Laser interactions and the performance of 2PP systems

Core Reading

- Chapter 4 and 15 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 7

Applications of Lithography II

Lecture Aims

- To introduce applications

Content

- Applications of SL and 2PP including Photonic crystals and medical applications

Core Reading

- Chapters 4 and 15 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 8

Material physics for AM techniques I

Lecture Aims

- To describe and/or recap prerequisite materials physics

Content

- Tensile, compressive and shear stress and strain
- Viscosity and flow in pipe as a model for FDM

Core Reading

- Chapter 13 and 15 : General Physics - Mechanics and Molecular Physics, L. D. Landau, A. I. Akhiezer, and E. M. Lifshitz. Pergamon. (1967).

Lecture 9

Material physics for AM techniques II

Lecture Aims

- To describe the flow properties and physics of plastics

Content

- Shear stress, strain, and viscosity
- Newtonian and Non-Newtonian flow
- Velocity profile of fluids in pipes
- Hagen-Poiseuille's equation for volume flow rate

Core Reading

- Chapter 13 and 15 : General Physics - Mechanics and Molecular Physics, L. D. Landau, A. I. Akhiezer, and E. M. Lifshitz. Pergamon. (1967).

Lecture 10

Fused Deposition Modelling I

Lecture Aims

- To develop a detailed understanding of fused deposition modelling (FDM) systems

Content

- The main components of a FDM system: framework, motion system, filament loading, and extrusion nozzle
- Approaches of different FDM machine motion types
- Introduction to physics of FDM

Core Reading

- A review of melt extrusion additive manufacturing processess: 1 Process design and modelling, B. N. Turner, R. Strong, and S. A. Gold, 192-204, Rapid Prototyping Journal, July 1992.

- Chapter 6 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 11

Fused Deposition Modelling II

Lecture Aims

- To understand materials physics properties under stress and flow as applied to FDM printing techniques

Content

- Stress and strain curves and thermoplastic FDM material properties
- Operation and calibration of a FDM machine
- Nozzle design and physics of molten plastic flow

Core Reading

- A review of melt extrusion additive manufacturing processess: 1 Process design and modelling , B. N. Turner, R. Strong, and S. A. Gold, 192-204, Rapid Prototyping Journal, July 1992.

- Chapter 6 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 12

Alternative AM techniques

Lecture Aims

- To describe powder-based and laminated AM techniques

Content

- Laminated object manufacturing
- Selective laser sintering
- Comparison of AM techniques and materials

Core Reading

- Chapters 5 and 8 : Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Gibson.

Lecture 13

3D Metrology and Surface Reconstruction I : Techniques

Lecture Aims

- To describe a variety of near and far field techniques that can be used to generate model surfaces

Content

- Near-field and Far-field 3D scanning techniques : Stereovision, structured light, coordinate measurement machines and Laser-based techniques

Core reading

- Chapter 2 and 3 : Computer Vision, D.H. Ballard and C.M. Brown, Prentice Hall.
  Available at http://homepages.inf.ed.ac.uk/rbf/BOOKS/BANDB/bandb.htm

- Chapter 2 and 7 : Three-Dimensional Computer Vision, Y. Shirai, Springer-Verlag (1987).

Lecture 14

3D Metrology and Surface Reconstruction II : Data processing techniques and algorithms

Lecture Aims

- To describe data processing approaches to produce mesh surfaces suitable for 3D additive manufacturing techniques

Content

- Volumetric data types (points, surfaces, voxels…)
- Data processing techniques for conversion and manipulation

Core reading

- Chapter 8-10 : Three-Dimensional Computer Vision, Y. Shirai, Springer-Verlag (1987).

Lecture 15

Course summary and worked questions

Lecture Aims

- To give a course summary and example questions

Content

- Course overview and structure

- Worked examples questions

Core reading

- Please read through your own lecture notes and compare with the lecture schedule. Please let the module convenor know if there are gaps and further clarification may be addressed in lecture.

Workshop I

Design Techniques I : Introduction to CAD

Workshop Aims

- To provide an overview of CAD software
- To introduce computation solid geometry and OpenSCAD

Content

- CAD software for design
- Constructive solid geometry (CSG)
- Introduction to the OpenSCAD interface

Core Reading

- M.L. Boas, (2006) *Mathematical Methods in the Physical Sciences* (3rd Ed) Wiley.
- Functional Design for 3D Printing (2nd Edition): Designing 3D printed things for everyday use, C. T. Smyth. CreateSpace Independent Publishing Platform. (2015)
- Mathematics for Computer Graphics (4th edition), J. Vince. Springer. (2014)

Workshop II

Design Techniques II

Workshop Aims

- To improve OpenSCAD design techniques

Content

Practical studies in:

- CSG basic objects
- CSG transformations (vectors recap)
- Boolean operations of CSG objects: Union, intersection, difference
- Parametric and algorithmic design examples

Core Reading

- M.L. Boas, (2006) *Mathematical Methods in the Physical Sciences* (3rd Ed) Wiley.
- Functional Design for 3D Printing (2nd Edition): Designing 3D printed things for everyday use, C. T. Smyth. CreateSpace Independent Publishing Platform. (2015)
- Mathematics for Computer Graphics (4th edition), J. Vince. Springer. (2014)

Workshop III

Design Techniques III

Workshop Aims

- To improve OpenSCAD design techniques

Content

- Practical studies of advanced CSG transformations
- Modularization and part design reuse
- Specialised CSG object-object products : Minkowski and Convex Hull

Core Reading

- M.L. Boas, (2006) *Mathematical Methods in the Physical Sciences* (3rd Ed) Wiley.
- Functional Design for 3D Printing (2nd Edition): Designing 3D printed things for everyday use, C. T. Smyth. CreateSpace Independent Publishing Platform. (2015)
- Mathematics for Computer Graphics (4th edition), J. Vince. Springer. (2014)

Workshop IV

Design Techniques IV

Workshop Aims

- To improve OpenSCAD design techniques

Content

- Control loops and structures
- Object and part libraries
- Design examples and extending them

Core Reading

- M.L. Boas, (2006) *Mathematical Methods in the Physical Sciences* (3rd Ed) Wiley.
- Functional Design for 3D Printing (2nd Edition): Designing 3D printed things for everyday use, C. T. Smyth. CreateSpace Independent Publishing Platform. (2015)

- Mathematics for Computer Graphics (4th edition), J. Vince. Springer. (2014)

Assessment

Written Examination (2 hours)	Weighting 60%
Coursework (Design and report)	Weighting 20% + 20% = 40%

Rationale for Assessment
Skills a) to e), f), h), i), j), and k) are assessed by Coursework.
Skills a) to g) are assessed by Examination.

Assessment Schedule

- Coursework: Contributing 40% to the overall module grade. The coursework is a design project to a given specification and 3D additive manufacturing system. The specification shall be provided prior to project week 1 in the above module timetable (24th March 2017) and formative discussion sessions are indicated as project weeks within the course schedule above. The submitted coursework shall comprise a selected final design and supporting report. The design and report contribute an equal weighting (20% each) to the overall mark contribution (40%). The deadline for submission of course work is **Friday 5th May 2017** at 5pm.

- Examination: Contributing 60% to the overall module grade and shall be 2 hours in length. The examination will comprise questions that offer the student opportunity to demonstrate their understanding through a mixture of numerical and discussion questions.

    - **Examination period is between Monday 15th – Friday 26th May 2017**
    - For students who fail this examination, the re-sit period is beginning of July 2017. **Please do not book holidays or return flights until after this period until you know that you have passed your examination.**

Coursework

The coursework will consist of a project with a practical and report component, both will form part of the final assessment with each carrying half of the marks

20% (practical design feasibility) + 20% (report on design documentation) = 40 % (coursework total)

NB: Problem sheets are to aid learning and understanding. They must be completed but do not contribute to the overall mark.

- Submission of work
    - You must submit your completed work as **hard copy** in the hand-in box situated on the ground-floor of building L.

Deadline for Coursework Submission

Coursework (design + report) **Friday 5th May 2017** at 5pm

Examination

Each student must sit the end of module examination which equates to 60% of the overall module grade. The examination is closed book.

Feedback

I aim to mark the coursework and have it available for your review within 3 working weeks of the hand-in date.

In terms of the examination, it is usual for the provisional marks to be disclosed following the programme examination board. Students do not receive their examination scripts back, but are able to make appointments to see the module convenor to discuss the examination and their work.

Factors outside my control may not always make it possible to return work on time, for example, if academic misconduct is detected it can delay the return of work for everyone.

This feedback will help you reflect on your performance, and make improvements so that you get the degree that you want. If you do not understand what you did wrong or what you did right, then seek advice sooner rather than later from the module convenor; you can also make an appointment to get help from your year tutor or your academic tutor.

ALL MARKS ARE PROVISIONAL UNTIL RATIFIED AT THE UNIVERSITY EXAMINATION BOARD

Help with your assignment

Help on your assignments is available from the module convenor on the module. You should make an appointment for a one-to-one seminar with the module convenor to discuss your work well in advance of the deadlines. The module convenor will not comment on completed draft assignments which you bring to a one-to-one seminar prior to the assessment deadline. **However the module convenor will comment on a draft answer plan for an assignment.**

These one-to-one seminar are a very important form of feedback, because this is where I can give you help and guidance before you hand the work in. How much you get out of the tutorial depends on:

(a) whether you attend or not.

(b) how well you prepare beforehand.

(c) how well you reflect on the meeting afterwards.

If you require help on an assignment or regarding the examination or any other aspect of the module, then it is best that you organise a one-to-one seminar. I will not be able to immediately respond to emails and in normal circumstances you can reasonably expect a reply within 48hours.

Tips on good academic practice

1. Allow yourself plenty of time to read textbooks, e-books, journal articles and so on. You may not be able to take in an entire article or chapter at one go; be prepared to break the reading down into smaller sections.
2. Preparation is needed before you start reading: Why are you reading this book chapter or journal article? What information do you want to take away when you've finished? Do you need all the information contained in the chapter(s) book and/or journal article, or are you going to concentrate on one section? What sort of material are you tackling (e.g. fundamental laws of physics, technical application of physics, etc)? Will this affect how you take notes?
3. Make sure you understand what you read. You can skim read something to see if it is relevant for your purpose, but once you've decided that the information is what you want, you have to be prepared to work at the reading. You need to read actively, rather than passively: That means thinking about what you read!
4. When you take notes, do not write down verbatim from the paper. It's very easy to forget that you've copied down a sentence, think that they are your words, use them in your essay. This would be plagiarism. If you must copy words, then note that it is a quote as you copy them. Better than this, though, is to read, understand, and then

summarise in your own words. If you can't do this, then you haven't understood what the author is saying. Use diagrams and drawings if this helps your understanding, and discuss what you've read. Share the reading and explain your reasoning to someone else – if you've understood, you should be able to make them understand.

5. When you write your essay or problem, be driven and guided by the question and your plan of how to answer it, rather than the purpose of the authors whose work you are citing.
6. Remain critical at all times. Never meekly accept a "fact" without asking where it came from, how it was established, and what its limitations are.

Examples of what I like to see in assignments

Is your work sophisticated and precisely and/or eloquently written with all the needed formula/equations given that makes reading your work a joy?

This doesn't mean using a thesaurus and showing all the passages of your calculations but to use simple words to explain your reasoning and the key passages of your calculations. It means thinking about ME, the reader! Will I understand it? Have you made your point clear? Will I have to struggle to follow your logic/reasoning/calculations, or do your points/calculations flow through skilful links and ordering?

Have you taken pride in your work?
I like to see that you have taken the time to check for spelling, grammar, punctuation, calculations, etc. You have handed in a well-crafted, polished piece of work.

Have you thought out your arguments?
Your points link together to explain and evaluate the main theme of your overall argument, and you present a well-balanced and objective consideration of the issues. You clearly understand the issue, rather than paraphrasing other people's ideas. You have written, reviewed, edited and re-drafted several times before committing to a final version. You indicate that you appreciate the temporary nature of our understanding, and the limitations not only in the specific pieces of work, but in the broader area and the paradigms involved.

Do you do what I asked you to?
You have placed your own interpretation on the task, possibly even presenting an original take on the question, but you have nevertheless completed the task in a direct and focused way.

Things that I strongly suggest that you avoid

Have you made sweeping statements that lack supporting authority?
You make vague generalisations that have no supporting authority and no context. The relevant is intermixed with the irrelevant, and I have no signposts to show me where you're starting, where you're going to and how you're going to get there.

Have you poorly presented your work?
I find it difficult to assess your work because the content is lost in poor structure, poor English, and poor explanation.

Have you left things to the last minute?
Rather than managing your time so that you can acquire an understanding of the concepts that you are writing about and calculations that you are making, and have plenty of time to prepare and reflect, you leave your work until the last minute. I then get a piece of work that is paraphrased from external sources (e.g. Wikipedia, any type of internet resource, etc), sloppy calculations or just the final result without showing how you got there and also explaining in words what type of reasoning you did to reach such a conclusion and/or numerical result and what it means, it reads as if it were a first draft or a set of notes cobbled together, and any link to the problem and/or question I gave you is largely due to coincidence. I spend longer on marking it than you did in writing it.

To summarise…
In your academic career you need to know how to communicate orally, visually and in writing. You should be able to write formal, scientific papers, and structure your work to provide both a logical flow and good, clear English. If you do still have concerns, you will find the Student Mentor workshops very helpful, and you can sign up for appointments to discuss your work. You also need to factor in time for thorough proofreading and correct referencing. This should be a task that you can now complete independently, but it does need time!

You can do all of the above on your own; what we need to do together is concentrate on increasing your depth of understanding, and encourage you to expand and develop your ideas. I am always happy to meet students to discuss their work, so email for an appointment or drop in during my office hours. Do some preparation before you arrive, so that you come with a clear idea of what you need to get from the meeting; specific questions ("What did you mean by…"; "Why is this evidence of…" "Can I interpret the question to show that…") can be useful. I will do my best to help you, whatever stage and understanding you have reached, but at this level, to get the most out of our meeting, you need to be prepared to be the driving force.

Meeting your deadlines

- You should plan to complete your work at least a three days before the deadline, so that you can spend time proof-reading, re-checking your calculations and your interpretation of the results and dealing with the administration of handing your work in.

- You are also responsible for organising your workload so that you can meet each and every one of your deadlines, even when several occur on the same day. If you need help with this, see your academic or year tutor.

- You are responsible for the safe storage of your work; you should keep two electronic copies (on different drives) of every piece of work. You should make sure that no-one can access your work without your knowledge and consent. If you have any difficulties with IT equipment, ask for advice at the IT helpdesk.

- If you have troubles with the Library, or uploading your document to MyModules, e-mail or visit the Applied Physics librarian, or go the Library drop in sessions.
- In Applied Physics, work handed in after the deadline will not be read, and will be awarded a mark of 0. Your mark for the re-sit piece of work will be penalised according to St Mary's University regulations. If you think that you will not meet a deadline it makes sense to seek help sooner rather than later. Please see the School Extenuating Circumstances Procedure below.

School Extenuating Circumstances Procedure

This School procedure relates to the late or non-submission of coursework, it does not apply to examinations.

What will happen if I do not submit my coursework, or submit it after the deadline?
If you fail to submit coursework by the deadline, or submit coursework after the deadline set by the Programme, you will receive a grade of zero for that assessment. Resit penalties will be applied, resulting in a cap of 40% being placed on that assessment, unless you make a successful extenuating circumstances claim for a resit without penalty.

What do I do if I think that I am likely to miss a coursework deadline?
If you think that you're likely to submit coursework work late, you must complete the University's Extenuating Circumstances form (available from your Programme Administrator or Registry) which must be submitted for consideration to your Programme Administrator directly with supporting evidence.

What do I do if I miss a coursework deadline?
If you miss a coursework deadline you will be notified by your Programme Administrator. If you wish to apply for a removal of penalty you must complete the University's Extenuating Circumstances form which must be submitted with supporting evidence and the completed coursework for consideration to your programme administrator **within 10 working days of the original deadline**.

After 10 working days, any extenuating circumstances submitted for consideration should be submitted to the University Exams Office directly with supporting evidence.

What types of extenuating circumstances will/will not be considered and what supporting evidence is required?
While it is stressed that a penalty for late submission will be removed for good reason and in line with the Extenuating Circumstances Policy as set out below (see table), it is also recognised that where a proper reason exists an extension or request for removal of a penalty will not be refused unreasonably.

Extenuating circumstances claim	Acceptable evidence	Not acceptable
Illness	Medical conditions which prevent attendance and which are supported by written evidence from a Medical Practitioner. (With regard to College Doctor's Notes, only medical conditions stated to a be moderate or very substantial degree will be considered)	Conditions which were not disclosed in good time for special arrangements to be made Ongoing medical conditions which are controlled by medication (unless the condition has worsened or the student has experiencing a relapse etc.). (With regard to College Doctor's Notes, medical conditions that are stated to be of a minor degree will not be accepted)
Stress or other emotional difficulties	Medical certificate or supporting letter from an appropriate professional including the college chaplain or counsellors	
A death of a partner or close family member. Students may miss an examination(s) when a funeral is arranged and/or may be considered if it has affected his/her studies	Death certificate (copies are acceptable)	
A death of a friend or acquaintance		Deaths of friends and acquaintances will not normally be considered (The College acknowledges that the death of someone other than a partner or close family member may cause considerable grief to certain students, and will deal sensitively with claims where this is explained.)
Personal injury which prevents a student from studying or taking exams	Medical evidence	
Where a student has been a victim of crime	Police crime report or report from appropriate support agency	
An elite sports person who is selected to participate in a major sporting engagement at national or international level.	Letter confirming participation	Sporting events where attendance is optional or it is not at national level
Trauma or severe personal loss e.g. victim of mugging, rape, or a witness of crime, serious fire or accident	Appropriate documentation to substantiate claim e.g. medical certificate, police report, accident report, etc	
Major Religious Festivals	Details of festival and signature from relevant religious leader	
Previously undiagnosed Special Need	Appropriate professional diagnosis of a special need of which the candidate was not aware at the time for valid reason.	Special needs which were known but for which special examination arrangements were not applied for in due time.
Miscellaneous		Circumstances which do not clearly relate to the timing of assessment Failure to manage study time effectively Accommodation problems Failure of IT or other equipment (either your

		own or college equipment) Financial problems Letters of support from Academic staff when the claim is un-supported by any independent documentary evidence. Holidays outside the vacation period Part-time work

What will happen after I submit the University's Extenuating Circumstances form?
Decisions on the removal of penalties for late submission, as with decisions on other extenuating circumstances procedures submitted up to 10 days after a coursework deadline, will be made by your Programme Director, or a person nominated by the Programme Director.

You will be informed by the Programme Administrator via email of the outcome of your application, usually within 5 working days.

Instances of remission of penalties for late submission will be recorded by the Programme Administrator. A list of all remissions approved at School level will be presented to the University's Extenuating Circumstances Committee. Any student requiring more than two remissions in one year will be seen by the Programme Director and appropriate advice given or suitable action taken.

What happens if I submit late formative coursework?
Work for formative assessment is submitted so that you can benefit from feedback. Submitting such work late is discourteous and disrupts the plans staff will have made in allocating time to provide the feedback. The penalty for late submission, therefore, is forfeiting any right to feedback. You may approach the member of staff who would normally read and comment on the work in order to apologise, present excuses and request feedback. In the case of late submission of formative work, it is entirely up to the member of staff to agree or not, and, if agreeable, to determine the time when such feedback will be given.

A Guide to Academic Conduct

Your learning during your time at St Mary's University is a journey of discovery as you progress through your programme. Whilst being supported and guided by the tutorial/supervisory team, you will also undertake your own research, preparation and planning as you construct your assessment tasks. This is a vital element of your learning, and it is important to remember that the assessments are an integral part of that learning – not simply a way of testing *what* you have learned.

That learning process only has meaning and value if you present your own thoughts, *your* analysis – *your* work.

That is the standard of academic conduct that we expect, and hope, our students attain – however, we do have procedures in place to address any apparent instances of academic *mis*conduct.

Academic Misconduct is taken very seriously by the University, and students should be aware that the consequences of such misconduct can be serious.

Examples of behaviours considered to constitute academic misconduct are as follows:

- copying work from reference sources or other students (**plagiarism**);
- using elements of your own work more than once and without referencing the original **(auto-plagiarism)**;
- working too closely together with other students to produce very similar submissions (**collusion**);
- allowing another student(s) to copy their work (**unfair advantage**)
- fabricating results or other outcomes that form part of the work (**falsification of data**);
- bringing unauthorised materials/electronic devices into an examination room, and/or behaving in other ways that could bring an unfair advantage (**examination cheating**).

Academic Misconduct – Guidelines for Students

The above represent the most common forms of academic misconduct, however, students should refer to the "Academic Misconduct – Guidelines for Students" on SIMMSpace in order to familiarise themselves with the more detailed information about the types of academic misconduct.

These Guidelines also explain the process that will be followed when a student is suspected of academic misconduct; and the types and levels of sanctions that will be applied when cases are proven.

Non-Academic Misconduct
Students should please note that Academic Misconduct and other forms of Student Misconduct are addressed via different processes.

Allegations of Misconduct which are not categorised as academic will be investigated and progressed by the Head of School or Service (or nominee) according to Section 4 of the Student Disciplinary Procedures.

Marking and Moderation Process

How is my work marked?
After you submit your work, it is marked by at least one tutor. All written exams or coursework in the University are required to be marked anonymously, i.e. your identity will not be known to your tutor as he or she marks the assignment. Your tutor should only be able to identify you by your regnum. Anonymous marking helps the University to ensure that the marking process is objective and avoids bias.

Not all assessment, such as presentations, can be marked anonymously due to the nature of the tasks.

In this module, the coursework and examination assessments will be marked anonymously.

Your work may then be subject to a process known as moderation. Moderation will generally involve a second marker checking a sample of work, along with the first marker's marks and comments, to verify the overall standard of marking and the use of the marking criteria.

Normally a sample of at least 10% of the written work for this module will be moderated and this will include a range of marks from the top, middle and bottom of the marking scale. All borderline fails, will be moderated.

The purpose of moderation is to provide an internal check on the marking to ensure that the marking criteria are applied in a fair and consistent manner and that marking within this module and between modules is consistent.

The marks of the first marker generally will stand unless the moderation highlights significant differences between the two markers. If there are significant differences, further action will be then be taken with the approval of the Programme Director.

Methods that can be used to resolve disagreements include the first marker reviewing the marks following feedback from the second marker, all assignments being second marked by the second marker or third marking of the sample by another tutor.

Where there is significant disagreement in terms of the general consistency of marking, for instance if the first marker has marked too harshly or too generously, the two markers can negotiate to adjust the marks accordingly for all students and not just those in the sample.

Marks for individual students will not be changed after moderation, except in cases of mathematical errors, when marking criteria have not been correctly applied or when all assignments have been second marked. This ensures that all students are treated fairly and equitably. If marks for individual students in the sample are changed, those students could benefit or be disadvantaged by being included in the sample of work that was moderated or second marked.

What happens next?

After your assignment is marked by your tutors, it is then subject to external moderation by an external examiner. The use of external examiners is standard practice across the university sector in the UK. Each programme at the University has at least one external examiner, who is often a tutor in the same subject area from another university.

Why is this important to you? External examiners provide an additional check on the marking carried out by your tutors. External examiners help to ensure that marking within modules and across the entire programme is consistent and that our regulations and procedures have been applied appropriately. External examiners are also responsible for ensuring that the standards of this programme are comparable with equivalent programmes at their university and other universities that they have worked or examined at.

External examiners will not see all assignments. They will agree a sample with your tutors in advance. However, external examiners do have the right to see all assignments if they wish. The agreed sample should contain those assignments that have been moderated or second marked and a range from the top, middle and bottom of the marking scale and first class or distinction marks, fail marks and borderline pass/fail marks.

External examiners do not act as another marker. They check the sample to see whether the marking is appropriate and consistent. If the external examiner suggests changes to the marks, as with internal moderation and second marking, the marks for all students on the module (not just those sampled) will be changed accordingly.

Examination Board Process

Once your assignments for this module have been marked and checked internally and by the external examiner(s), the marks are then approved by the Programme Examination Board, which meets at the end of each semester or assessment period.

In relation to this module, the Programme Examination Board is specifically tasked with approving:

1) The mark for each individual assessment for each student;
2) The overall module mark (percentage and grade) for each student;
3) Internal module compensation (see below) for students who are eligible.

Assessment Failure and Internal Module Compensation

If you fail the coursework or examination assessment you will be required to re-sit the assessment at the next available opportunity. Unless you have valid extenuating circumstances, the re-sit of that particular assessment will be capped at 40%. If you fail to undertake a re-sit, your mark for that assessment will be reset to 0. Each assessment in a module is subject to a maximum of three attempts.

At the Programme's discretion, following careful consideration as to whether the learning outcomes of a module have been met, the programme may internally compensate the module. Internal module compensation may be applied if you achieve the pass mark for the module but have not passed each individual assessment. This would mean that you would not be required to resubmit the failed assessment.

Contrary to the University Academic Regulations, compensation in the Applied Physics programme is a last resort and is permitted provided that the failed assessment has a mark of no less than 30%.

Please also note that in order to progress into Level 5 (year 2) you need to have passed a minimum of 100 credits. Therefore if you fail more than 1 module you will be unable to progress into Level 5.

More details on the Examination Board process can be found in the Programme Handbook.

ALL MARKS ARE PROVISIONAL UNTIL RATIFIED AT THE UNIVERSITY EXAMINATION BOARD

Grading Criteria for written work – level 6 (year 3)

Criteria for Written Work – Level 6 1st Class 80% +	Demonstrates substantial intellectual self-confidence and originality of thought. Shows a rigorous understanding of key aspects of the topic and a thorough acquisition of coherent and detailed knowledge. Incisive argument is sustained throughout, bringing together theory and practice where appropriate. Organises material systematically. Makes critical use of a very wide range of scholarly literature and primary sources. Work is set within the context of current research in the field and of ideas with techniques which are at the forefront of the discipline and shows an impressive understanding of the limits of knowledge. Shows impressive qualitative and quantitative ability where appropriate. Writing is polished, accurate and fluent. Presentation uses appropriate scholarly conventions.
1st Class 70-79%	Demonstrates intellectual self-confidence and originality of thought. Shows a rigorous understanding of key aspects of the topic and a thorough acquisition of coherent and detailed knowledge. Incisive argument is sustained throughout, bringing together theory and practice where appropriate. Organises material systematically. Makes critical use of a wide range of scholarly literature and primary sources. Work is set within the context of current research in the field with of ideas and techniques which are at the forefront of the discipline and shows an excellent understanding of the limits of knowledge. Shows impressive qualitative and quantitative ability where appropriate. Writing is polished, accurate and fluent. Presentation uses appropriate scholarly conventions.
Upper-Second Class 60-69%	Demonstrates a rigorous understanding of key aspects of the topic. Shows acquisition of coherent and often detailed knowledge. Argument is sustained, focussing consistently on the title / question. Organises material systematically. Makes critical use of appropriate scholarly literature and primary sources. Shows awareness of current research in the field, and of ideas and techniques which are at the forefront of the discipline and shows a good understanding of the limits of knowledge. Shows qualitative and quantitative ability where appropriate. Writing is accurate and fluent. Presentation uses appropriate scholarly conventions.
Lower-Second Class 50-59%	Demonstrates a good understanding of key aspects of the topic. Shows acquisition of coherent and often detailed knowledge. Argument is sustained, but could be developed further in places. Organises material effectively. Makes critical use of appropriate scholarly literature and primary sources. Shows awareness of current research in the field with ideas and techniques which are at the forefront of the discipline and shows an understanding of the limits of knowledge. Shows qualitative and quantitative ability where appropriate. Writing is generally accurate, but shows occasional errors of grammar and syntax.
Third Class 40-49%	Demonstrates some understanding of key aspects of the topic. Shows acquisition of coherent and sometimes detailed knowledge. Argument is sustained, but lacks depth, rigour and complexity. Engages with appropriate scholarly literature and primary sources. Shows awareness of current research in the field with of ideas and techniques which are at the forefront of the discipline and shows some understanding of the limits of knowledge. Shows reasonable qualitative and quantitative ability where appropriate. Writing often

	lacks fluency, clarity and precision and requires both proof reading and redrafting.
Fail **30-39%**	Misunderstands or is confused about key aspects of the topic. Presents some appropriate knowledge and evidence base, but handles these superficially. Argument is present, but is insufficient or incoherent in parts. No sustained engagement with the set title / question. Has used some appropriate texts, but does not use a sufficient range of scholarly literature and primary sources at this level. Writing is marred by continual errors of grammar, syntax and spelling. Presentation is poor and ignores appropriate scholarly conventions.
Poor Fail **0-29%**	Misunderstands or is confused about key aspects of the topic. Presents some appropriate knowledge and evidence base, but handles these very superficially. No sustained argument is presented. Written work may be very brief and / or unfinished. Very little engagement with the set title / question. Has used inappropriate texts for honours degree level work. Writing is marred by continual errors of grammar, syntax and spelling. Presentation is poor and ignores appropriate scholarly conventions.

Marking Analysis Sheet

Level 6 (Year 3)

Moderation

SCHOOL OF SPORT, HEALTH AND APPLIED SCIENCE

Please fill in the student self-assessment below before handing in your work.

OVERALL MARK: (provisional until Exam Board)

APH6010 3D Manufacturing

Title : Practical design and report

Regnum:_____

Assignment Outcomes:

- **To demonstrate 3D printing principles and understanding in a practical additive manufacturing design study to a given specification**

DESCRIPTORS	%	DEGREE EQUIVALENT
Outstanding	80+	First
Excellent	70-79	
Good	60-69	2:1
Satisfactory	50-59	2:2
Weak	40-49	Third
Unsatisfactory	0-39	Fail

STUDENT SELF-ASSESSMENT

Before you hand in this assignment, give your own evaluation of this piece of work by highlighting areas that you have improved upon since your last coursework submission. This is a self-appraisal and will not influence the marks awarded.

Identify areas improved on since your last submission:

Reflections on this piece of work (after it has been graded):

Student Signature …… Date ……

Overall comments and targets for future development of student work:

Staff Signature …… Date ……

1. Coursework – Final Design Feasibility (50%) /50

	1st	1st	1st	1st	2:1	2:2	3rd	F	F	F	F	
• **The final design meets all aspects of given specification** • **The practical design has been communicated unambiguously through technical drawings or other means.** • **The final design is within the capabilities of the chosen 3D manufacturing system.** • **Aspects of the final design do not meet the given specification.** • **The design requires further minor clarification in order to be manufactured.** • **It is marginal that the design can be produced on the given system (i.e. no margin of uncertainty has been reflected in the design).**	20	18	16	14	12	10	8	6	4	2	0	• **The final design is not feasible for the indicated additive manufacturing system.** • **The submitted design does not meet a majority of specification statements.** • **The design cannot be produced due to a lack of dimensional or other information**

2. Coursework – Report on Design Process (50%)

/50

1st	1st	1st	1st	2:1	2:2	3rd	F	F	F	F
20	18	16	14	12	10	8	6	4	2	0

- **The design specification has been clearly understood and reflected in the report.**
- **The report demonstrate an understanding of the limitations of additive manufacturing techniques and intended system.**
- **All steps towards the final design have been documented clearly.**
- **Supporting calculations are correct and concise notes describe the steps involved.**
- **The majority of the following statements apply:**
  - **The report describes and follows a logical plan**
  - **The documentation includes evidence of wider research of relevant community designs**
  - **The work critically evaluates cited relevant examples**
  - **The final design feasibility is supported by reported evidence**
  - **There is a clear progression in the steps towards the final design**
  - **Any supporting numerical calculations are correct and supported by descriptive text**
- **A minority of the previous statements apply.**
- **The report documentation shows**
  - **Poor or no evidence of planning**
  - **Little or no cited design examples**
  - **Little or no critical discussion of cited examples**
  - **Supposition within conclusions with little or no supporting evidence**
  - **Supporting numerical calculations are incorrect and do not support subsequent statements**