Third year group projects – Ed McCann B69 Physics ed.mccann@lancaster.ac.uk

- Introduction
- Practicalities
- Management Structure and Project Planning
- Meetings and Minutes
- The Projects
- Things To Do This Week

Introduction

- Why do we have group projects?
- Aims and learning outcomes
- The philosophy of open-ended projects
- Work load

Why do we have group projects?

The ability to work with colleagues in a team is a vital skill, both in academia and industry. You can develop generic skills including:

- organisation
- delegation
- effective communication
- leadership
- co-operation

Also, group work gives you the chance to learn from other students. There are benefits from discussing your own ideas and receiving feedback from your peers.

The philosophy of open-ended projects

The module is very open-ended:

- There is no manual telling you what to do.
- It is up to you and your team to plan and run your project.
- Guidance will be given on organising (planning, managing & executing projects).
- You will have regular meetings.
- Team meetings should be documented (minuted).
- Minutes and planning information must be submitted with your report.

Work load

- This module is worth 20 credits.
- This is roughly equivalent to two standard five-week modules, it's worth 1/6th of the 3rd year.
- The rating of 20 credits equates to 200 hours, spread over 10 weeks, i.e. 20 hours per week on average.

Timing

Week	Activity
Week 1	• Introduction to the module and project descriptions • Guidance on project management, planning, meetings • Selection of teams and projects
Weeks 1-2	• Develop roles within the teams • Initial investigations/exploring of the problem and potential solutions • Prepare research plans and presentation
Week 4	Submit research plan for informal feedback
Week 4	Group presentation to the class – research plans
Weeks 3-7	Execute project – including weekly team meetings
Week 17	Submit plan of the report for informal feedback
Weeks 8-10	Write report – including weekly team meetings
Week 10	Group presentation to the class – research results
Week 10	Submit report
Post exams	Individual presentation at the PLACE mini-conference

Assessment - Report

Components	Weight	Description
Report	50%	Written and assessed as a group
Log book	15%	Written and assessed individually
Peer assessment	20%	An individual mark allocated by your teammates
Mini-conference	15%	An individual presentation at the PLACE mini-conference

Report (50%)

Each group should submit a single report and every group member will receive the same mark for the report.

A project plan and minutes of weekly meetings should be included in the report as appendices.

Assessment – Log books

Log books (15%)

- Are compulsory, and should be completed by every individual
- Should be a contemporaneous record of everything you did as an individual in your project
- Should have all entries dated
- Should not be a final 'best' version
- Will be signed by the lecturer each week
- You will have your own "Individual Logbook" in OneNote on the PHYS379 Teams page. This is your own private space, it can't be seen by other classmates, but it can be seen by the lecturer.
- Please read the departmental guidelines on Logbooks and OneNote.

Assessment – Peer Assessment

Peer assessment (20%)

- Each team member will submit an individual mark between -6 and +6 for each of their team-mates.
  - One mark corresponds to one sub-letter grade.
  - Marks should be accompanied by short justifications.
  - Team members do not assess themselves.
- The marks submitted by each team member will be normalised by subtracting the average (forcing an average of zero).
- The set of normalised marks allocated to each team member will then be averaged and rounded to the nearest integer.
- The peer assessment mark is given by the group report mark plus this average, where one mark is one sub-letter grade.
- Peer assessment marks are **confidential**, and will not be seen by the other students. However, they may be viewed by the course lecturers and examiners, and can be moderated.

Assessment

The PLACE conference (15%)

All 3rd and 4th year physics majors are required to participate in the annual Physics conference which is held in week 27.

The conference is worth 3 credits, it is 15% of PHYS379.

The conference work is done individually and it can be about work conducted either during the independent study or the group project.

You are required to submit a short lay summary (30%) and to give a short talk (70%). An introductory lecture, teaching session and workshop will be given to the whole year group in the Summer Term.

Management structure and project planning

- Management structure
- Project planning
- Send me a short plan (1 page A4 + a Gantt chart) by Monday of week 4 (Mon 1st Feb). This will not be assessed.

Management structure 1

A well-managed project will have some or all of the following elements:

- Coordinator: The coordinator or leader has the task of ensuring the successful overall running of the project. (Political equivalent: Prime Minister)
- Secretary/administrator: This person's job is to ensure effective communication within the project, arrange meetings, take and circulate minutes. (Cabinet secretary, civil servant etc.)
- Committee: A 'reasonable size' group of people who discuss any issues and make all the (major) decisions. (Cabinet)
- Work-package leader: Activities within a project are broken up into a number of work packages, each of which have a leader or chair. (Minister)

Management structure 2

- Client/customer: This is the person/organisation that pays. They need to be informed and consulted, e.g. by reports. Note that reports are always required from projects, even when they are entirely contained within a single organisation. For the group project, you can consider the customer to be the lecturer. (Political equivalent: Us)
- Decision-making process: A project needs a well-defined decision-making process. Consensus is, in general, good practice for small projects, but even then a formal (voting) process is needed when consensus can't be reached. (Constitution)
- Plan: Successful operation of the project will depend on everyone involved knowing what needs to be done when, who is responsible for doing it, and what the rules are. This information will be contained in one or more (binding) documents. (Written constitution, manifesto)

Project planning 1

Good planning is vital for the success of a project, and comprises the following elements:

Work package (WP): A work package is a coherent set of activities (tasks) that work together towards a common sub-goal or goal in the project. Work packages have a well-defined start and duration and well-defined measureable outputs (deliverables).

Task: A Task is a single, well-defined activity. It will have a well-defined start and duration, but may not always have a formal deliverable, although it must always have some output.

Note

Management etc. activities may also be tasks and included in their own WP.

Your projects are small, so you may decide WPs are not necessary.

Project planning 2

Deliverables: A deliverable is a well-defined quantifiable (measureable) output from a WP or task. It could be a device, a part of a larger system, a piece of code, a measurement, a report etc. As the name implies, deliverables are the return on the investment for the client.

Milestones: Milestones are named after milestones in the road that tell you how far you have come and/or how much further there is to go: they are points in the project where progress can be assessed.

Milestones may be decision points, i.e. where you decide to choose one particular approach over another.

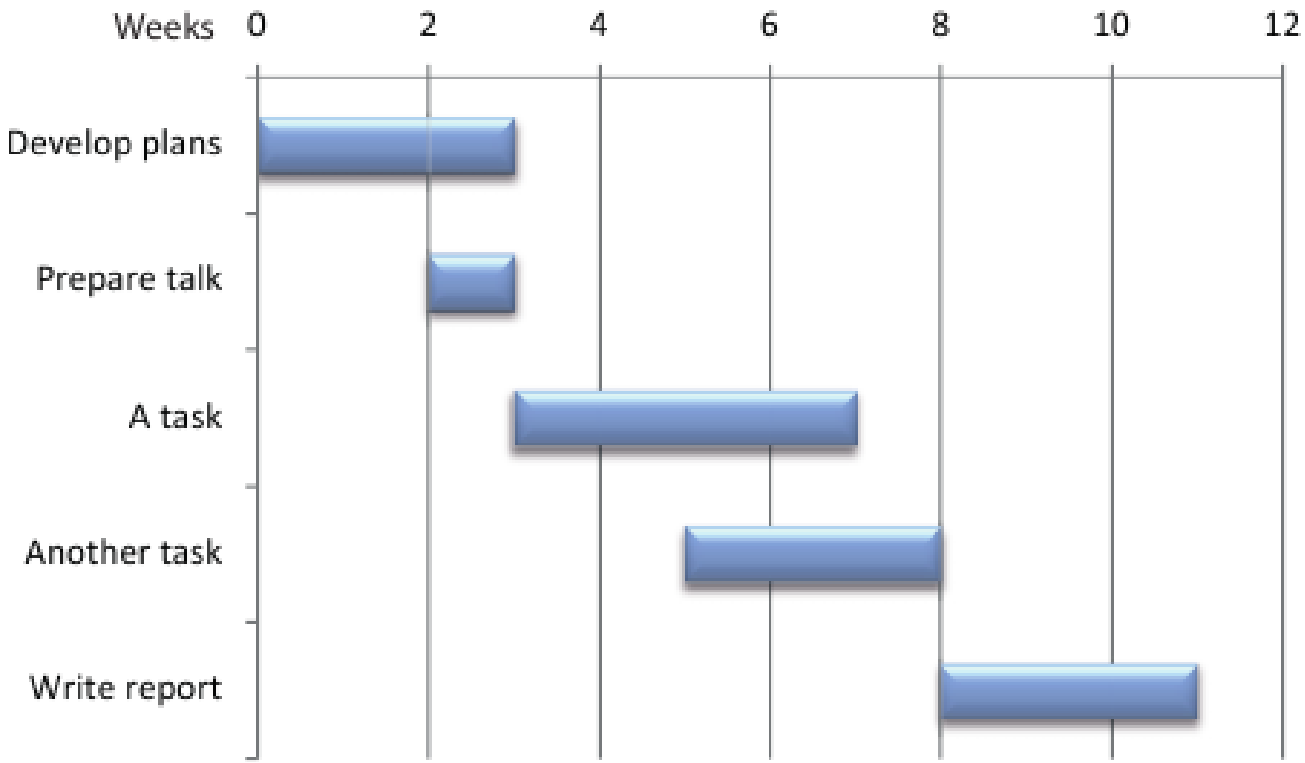
Milestones may come in the form of deliverables, but deliverables aren't always milestones.

Project planning & Gantt chart

Gantt chart: This is the master plan for the timing of the project. It should specify the timing of all the tasks and WPs. It may also show the timing of the milestones and deliverables as well as the interaction between tasks. (However, the Gantt chart should also be practical, and making it very complex may not achieve this).

Special software is available for generating Gantt charts, but using any reasonable method (e.g. Excel) is fine.

A crude Gantt chart is shown to the right.



Meetings and minutes

- Roles within a meeting
- Agenda and minutes

Roles within a meeting

A formal procedure backed up by documentation helps to avoid misunderstandings and disputes about what was agreed and who is responsible for taking any action;

Also, a well-defined structure helps meetings to run smoothly. The two principal characters are

Chair: The person in charge of the meeting. Note that keeping a meeting to time whilst also keeping the peace can be a difficult job (and a useful skill).

Secretary: The person who takes the minutes. The chair and secretary may be the same person, but doing both jobs at the same time may not be effective.

For the group project you may want to try rotating these roles within your group, but this is not compulsory.

Agenda and minutes 1

Agenda

Should be available prior to the meeting so that participants can come prepared.

An agenda will typically have the following items:

- Apologies for absence
- Minutes of the previous meeting - in case anyone disputes anything in them
- Matters arising - here any items are discussed for which there was an ‘action’ on someone in the minutes to see if action was taken
- Meeting-specific items, as required
- Any other business - things that didn’t get on the agenda, e.g. because they came up too late

Agenda and minutes 2

Minutes

Should accurately document the meeting. They do not need to record everything in fine detail: just the main points discussed, any decisions taken, and noting any ‘actions’.

The minutes of a meeting will look similar to the agenda:

- Attendance list (those actually present)
- Apologies for absence (list)
- Minutes of the previous meeting - approved OR amended (with amendments noted)
- Matters arising - the action taken is minuted
- Meeting-specific items, as required
- Any other business

Teams

- On the PHYS379 Teams page, every group will have their own channel. Here you will be able to share material and collaborate.
- You can have group meetings using this channel.
- In addition, you should have a meeting (as a group) with the lecturer every week in person on Friday.
- Meetings with the lecturer will be in the time slot 12pm – 4pm on Friday.
- You do not need be present for the entire 4 hours! I will publish a timetable for 30 minutes slots once the groups have been established.
- There will be some examples when we all meet, e.g. for group talks on Friday week 4 (11th February) and on Friday week 9 (18th March).

The theory group project topics

1) Cellular automata
2) Quantum computer simulator
3) Machine learning
4) Topology in tight-binding models
5) Chaos
6) Spins on lattices

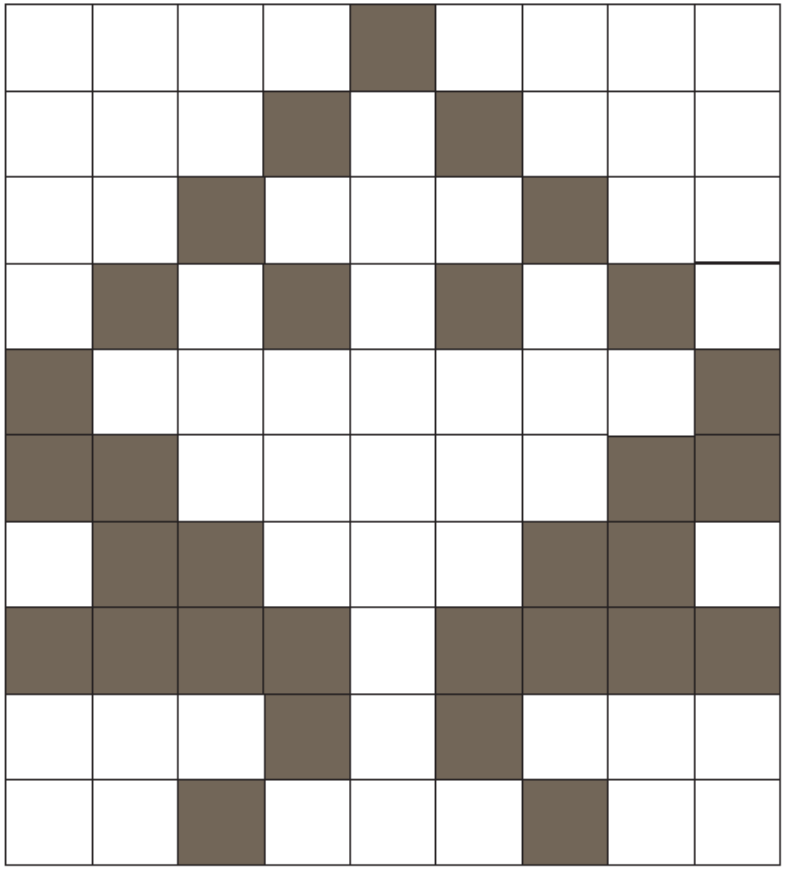
NB: each topic contains many possible projects

Chosen so:

- You can make progress and get to a non-trivial place (at least using numerics) within a few weeks
- Little or no overlap with other project work

Topic 1: Cellular Automata 1

A lattice of sites (or “cells”) such that the state of each site changes with time according to a rule depending on the local neighbourhood around the site.



This is a 1d automaton, each row is a state of the system evolving with time down the page.

In this case, “rule 90” dictates that a cell is occupied only if an odd number of its nearest neighbours were occupied at the previous time step.

Topic 1: Cellular Automata 2

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- 1d automata with more complicated algorithms.
- Coarse graining of a 1d cellular automaton.
- 1d (or quasi 1d) automata: Traffic models
- 2d automata: `Conway's game of life'.
- Probabilistic cellular automata: forest fire models.
- Sandpile and earthquake models. Self-organised criticality.
- Cellular automata models of fluid flow: lattice gas models.
- Cellular automata models of galaxy formation.

2d cellular automata are relatively easy to model; lots of possible different projects

Topic 2: Quantum computer simulator 1

Simulate a quantum computer using a regular pc. (i) A state in a 2-qubit system is

$$|\Psi\rangle = a|00\rangle + b|01\rangle + c|10\rangle + d|11\rangle \equiv \begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix}$$

(ii) The action of a quantum gate is represented by a matrix, e.g. a CNOT gate:

$$\text{CNOT} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

(iii) Then, a measurement is made and the system collapses into a basis state. The probabilistic nature of this can be modelled using a random number generator on a pc.

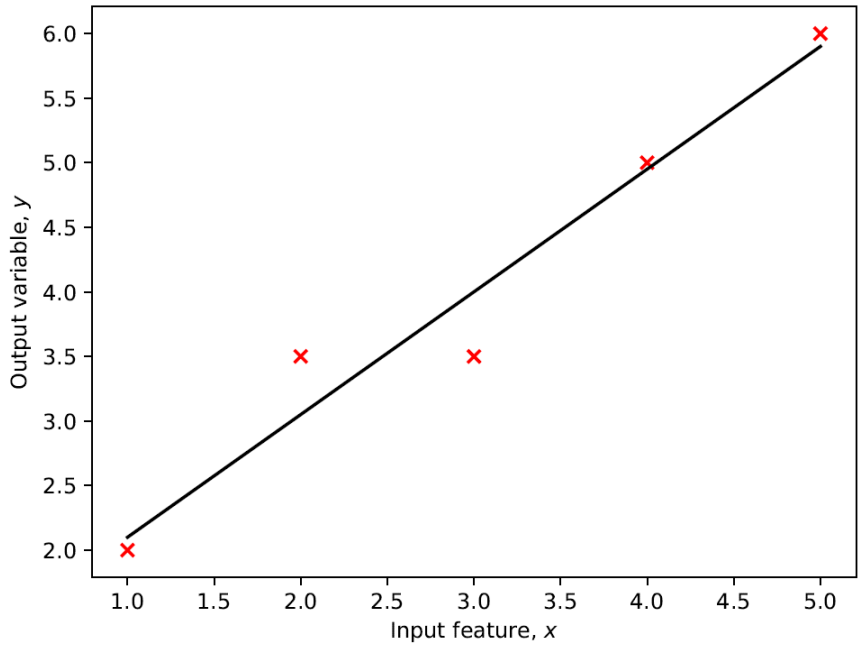
Topic 2: Quantum computer simulator 2

- Simulate a quantum computer (i) initialise a state; (ii) perform some quantum operations; (iii) measure the final state.
- Several quantum algorithms to implement, e.g.:
  - Grover search algorithm
  - Deutsch algorithm
  - Shor factoring algorithm
- Quantum teleportation

Fairly straightforward to do something in this topic, but advanced things may get quite complicated.

Topic 3: Machine learning 1

Simplest example: supervised learning, e.g. a linear fit to some data.



In this example, there are 5 “training examples” each with only 1 feature x; the line of best fit is a prediction.

The challenge is to deal with many training examples and many different features.

Topic 3: Machine learning 2

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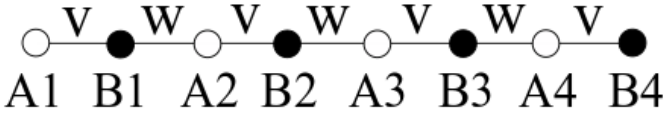
- Prediction of material properties (e.g. semiconductor or superconductor) using linear regression.
- Surveying a group of people to see if there's a trend (e.g. do people with blue eyes prefer tea to coffee?).
- Prediction of song genre using the Million Songs Database.
- Handwriting recognition.
- Spam filtering using the bag-of-words model.
- Classifying social media posts based on their language.

The challenge here is to find a project with data containing many training examples.

Topic 4: Topology in Tight-Binding Models 1

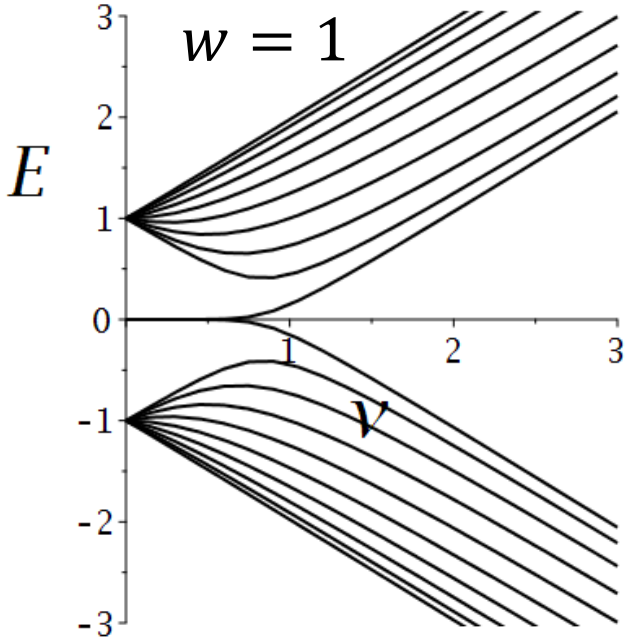
SSH model:



$$H = \begin{pmatrix} 0 & v & 0 & 0 & 0 & 0 & 0 & 0 \\ v & 0 & w & 0 & 0 & 0 & 0 & 0 \\ 0 & w & 0 & v & 0 & 0 & 0 & 0 \\ 0 & 0 & v & 0 & w & 0 & 0 & 0 \\ 0 & 0 & 0 & w & 0 & v & 0 & 0 \\ 0 & 0 & 0 & 0 & v & 0 & w & 0 \\ 0 & 0 & 0 & 0 & 0 & w & 0 & v \\ 0 & 0 & 0 & 0 & 0 & 0 & v & 0 \end{pmatrix}$$

Topic 4: Topology in Tight-Binding Models 2

SSH model:



Topological insulator

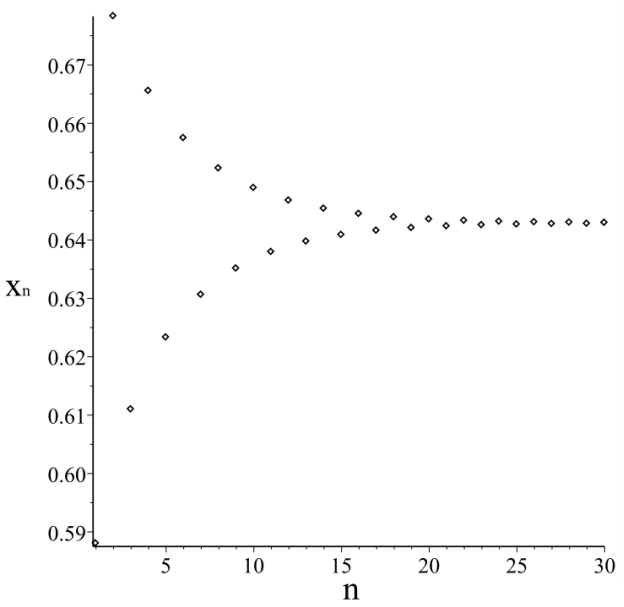
Topic 4: Topology in Tight-Binding Models 3

- Long-range hopping terms and disorder.
- Two coupled SSH chains.
- Two-dimensional lattices, e.g. honeycomb, Lieb, Kagome.
- Topological superconductivity.
- Non-Hermitian models.

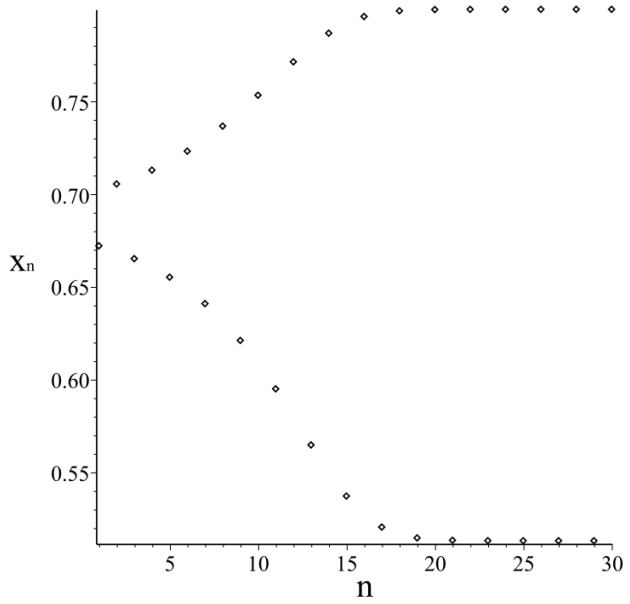
New topic.

Topic 5: Chaos 1

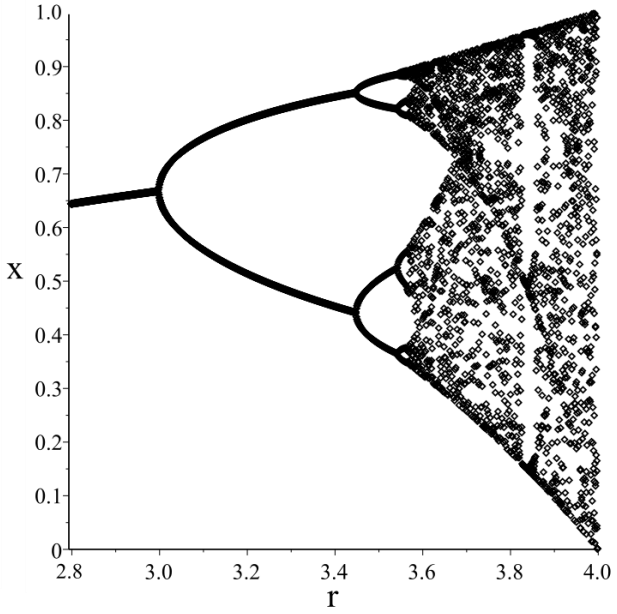
Logistic map: $x_{n+1} = rx_n(1 - x_n)$



$x_0 = 0.3, r = 2.8$



$x_0 = 0.3, r = 3.2$



bifurcation diagram

Topic 5: Chaos 2

- Higher-dimensional maps.
- Pendulums: driven/damped simple pendulum; double pendulum.
- Kicked systems.
- Two-dimensional billiards.
- Chaotic scattering.

Can be numerically challenging, e.g. how do you distinguish between chaos and the effects of numerical error due to an imperfect algorithm?

Topic 6: Spins on lattices 1

Ising model, every site on a lattice is 'up' or 'down' $s_i = \pm 1$

$$E = -J \sum_{\langle i,j \rangle}^{N} s_i s_j - h \sum_{i=1}^{N} s_i \,; \qquad M = \sum_{i=1}^{N} s_i$$

For four spins:

E = - 4J - 4h E = - 2h E = 4J

Thermal averages (canonical ensemble):

$$\langle E \rangle = \frac{1}{Z} \sum_{\ell} E_\ell e^{-E_\ell / k_B T} \qquad Z = \sum_{\ell} e^{-E_\ell / k_B T}$$

Can be determined using a Monte Carlo (repeated random sampling) algorithm (Metropolis).

Topic 6: Spins on lattices 2

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- Ising model in 2d – phase transition?
- External magnetic field.
- Antiferromagnetic coupling. Triangular lattice. Frustration.
- Other spin models – xy model, Heisenberg model.
- Defects.
- Analytic methods – transfer matrix methods.

Can be numerically challenging, e.g. being able to simulate large system sizes in order to see phase transitions.

Things To Do This Week

- Read the materials on Moodle.
- Complete the Moodle questionnaire by 12 noon on Friday 20th.
- Write something (e.g. “hello world” and the date) in your logbook on Teams by 5pm on Friday 20th.
- Look out for message on Teams on Friday 20th about the allocation of groups and projects.
- Find the time of your meeting on Tuesday 24th.
- Post in the channel on Teams for your group.