Physics of medical imaging and radiotherapy

BSc/MSci Physics level 3
7.5 ECTS course in term 2

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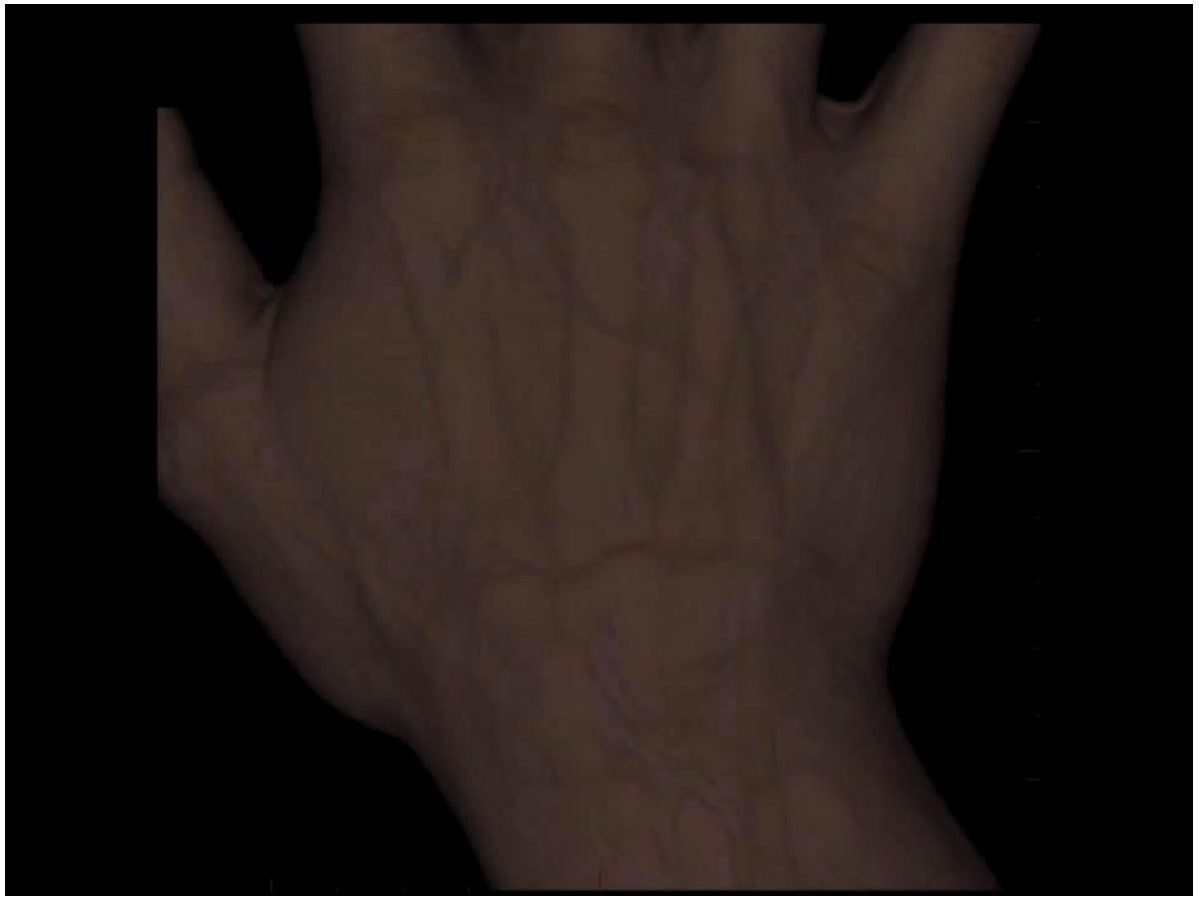
- The discovery of X-rays (Röntgen 1895) kick-started the field of medical imaging

- Developments in understanding and technology has led to far superior image quality



- and has been extended to full 3D tomography

Key developments in medical imaging

1895 – First x-ray image by Röntgen (NP 1901)

1896 – Becquerel finds radiation from uranium (NP 1903)

1898 – Marie and Pierre Curie find radiation from polonium and radium (NP 1903)

1910 – Krause, Bachem and Günther use barium sulphate as contrast agent

1926 – Forssmann places catheter in own heart and takes x-ray image (NP 1956)

1946 – Purcell and Block demonstrate Nuclear Magnetic Resonance (NP 1952)

1956 – Anger: first gamma camera

1958 – Donald: ultrasound of unborn child

1971 – Hounsfield: first x-ray Computed Tomography (CT) scanner (NP 1979)

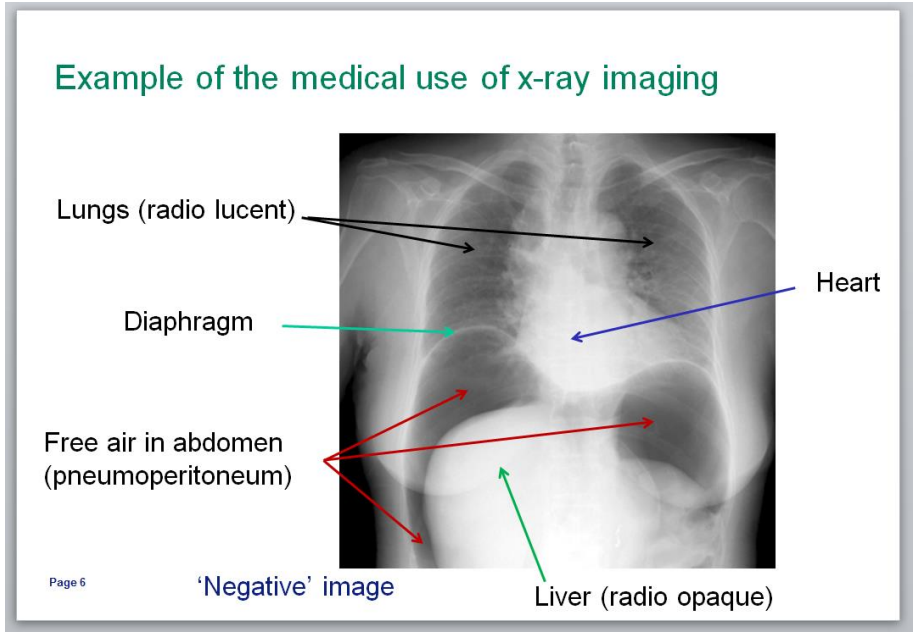
1973 – Lauterbur: first Magnetic Resonance Imaging (MRI) (NP 2003)
→ Mansfield

1975 – Pogossian: Positron Emission Tomography (PET) scanner

Aims:

- insight into the state of the art of medical imaging technology
- to introduce the physical principles behind:
  - interaction of radiation with biological tissue
  - generation & detection of radiation
  - signal and image processing
  - radiation used for therapy

Don’t worry, you will not be expected to learn biological/medical terms.



Course Structure:

- Overall
  - 18 lectures/seminars covering core examinable material
  - Assessed by a summer examination
  - 50% contribution to course mark
- You will get
  - Lectures; number varies, but, usually between 1 and 3 per week
  - Additional study material
  - 1st in-person seminar
    - Introduction to Projects and Problem Sheet exercise
  - In-person seminars 2 & 3
    - Work on “Problem Sheet” exercise
  - 4th in-person seminar
    - Peer-assessment of “Problem Sheet” exercise – more details in a bit…

Lectures 2—6: X-ray imaging and tomography

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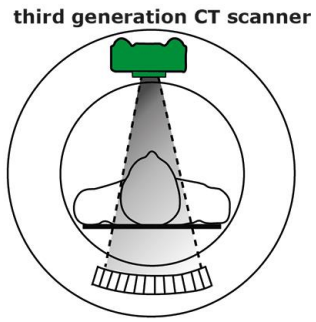
X-ray

X-ray CT



Lectures 7—9 and Seminar 4: Nuclear imaging

γ-cam/SPECT **PET**

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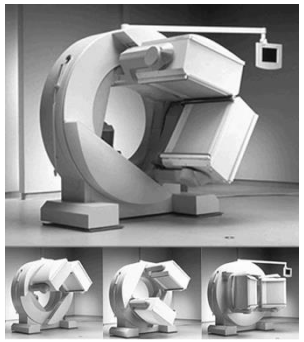

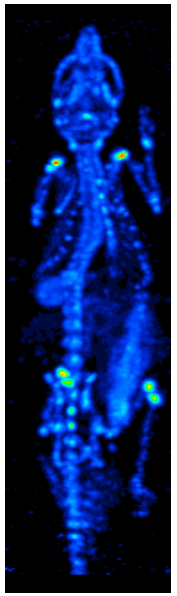

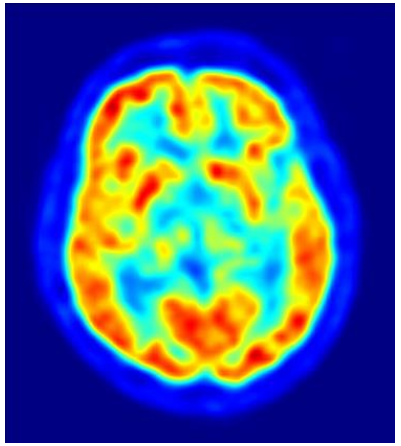

Lectures 10—12: Radiotherapy

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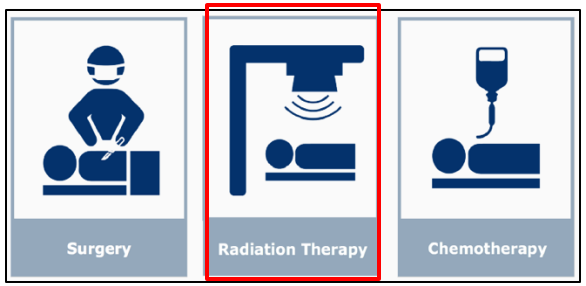
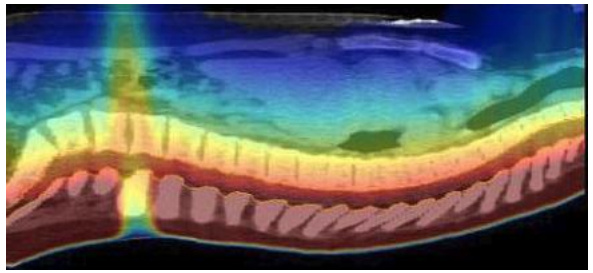
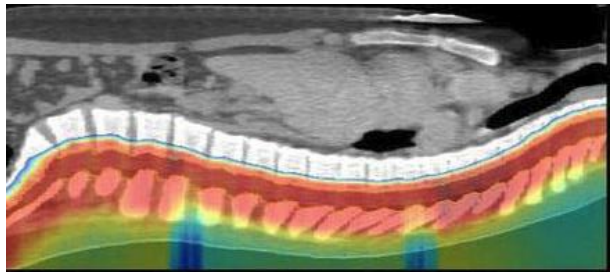


X-ray/photon therapy



Proton-beam therapy



Lectures 13—15: Ultrasound Imaging

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Ultrasound

Lectures 16—19 and Seminar 6: MRI

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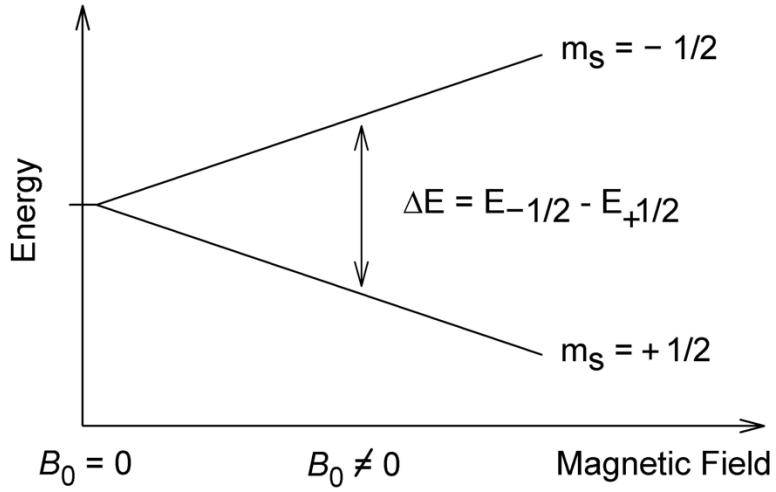
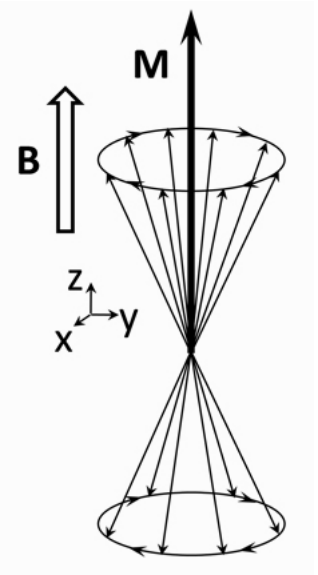
MRI





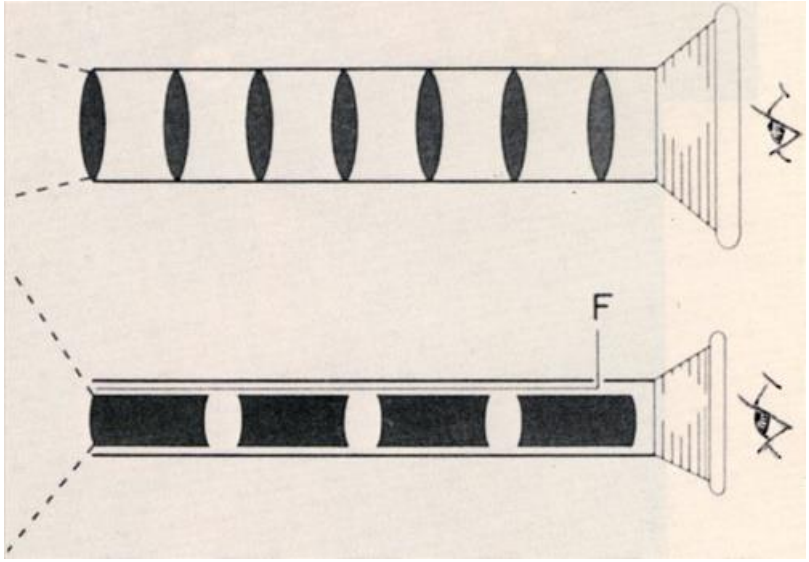
Format for seminars

- Learning by teaching
  - Harold Hopkins "*Only when you try to teach something do you discover whether you truly understand it.*"
  - Richard Feynman – The Feynman Technique
    - Pretend to explain a concept to an inanimate object, e.g. a rubber duck
    - Identify gaps in your knowledge
    - Review notes and textbooks
    - Explain it to someone else
- Seminars and topics:
  1. Introduction to Projects and Problem Sheet question exercise
  2. Work in groups on Problem Sheet exercise
  3. Work in groups on Problem Sheet exercise
  4. Peer assessment of Problem Sheet exercise

Aside: Rigid (Hopkins) endoscopes

- high quality image
- is the basis for most modern rigid endoscopes
- large number of pixels
- can offer a very large field of view, e.g. 80°…
- …but can't see round corners!

Hopkins' rod lenses greatly simplifies alignment and manufacture (bottom)



http://www.karlstorz.com/cps/rde/xchg/SID-03A4C631-05538108/karlstorz-en/hs.xsl/2411.htm

Aside: Flexible fibre bundle endoscopes

- image guided by fibre bundle
- each core guides light by total internal reflection
- up to 30,000 cores in a bundle
- used routinely for flexible clinical endoscopy until the development of miniature CCD cameras

NATURE January 2, 1954

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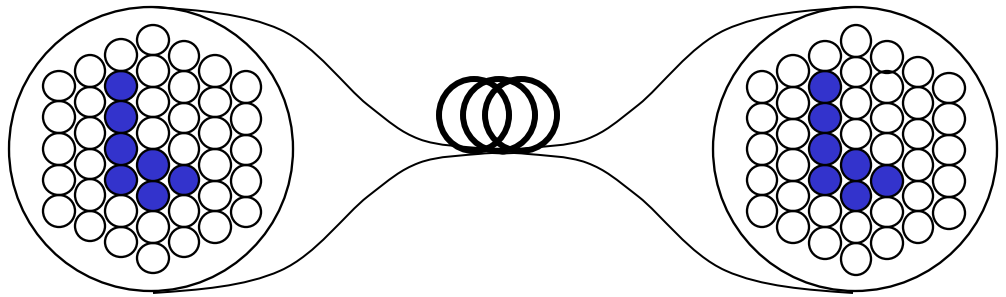

Course Structure: Weeks 7-8

- Problem Sheet Question and Answer exercise
  - Worth 5% of the final mark
  - Topic will be linked to that of the Project, see following slides
  - Group members will be the same as for Project
- Working in a group you will:
  - Week 7
    - Prepare a problem sheet-style question with answers on an assigned topic
    - The question and answers should take you 2-3 hours to prepare
    - Aim is that someone else in the class should take ~20 mins to complete it
  - Week 8
    - Individually assess the problem sheet-style question and answers prepared by 3 other groups
    - During seminar 7, your group will assign a single mark (out of 10) for each of the other 3 groups' questions
    - This will then be combined with a mark (out of 10) from a member of academic staff to give the overall mark for the exercise (out of 20)

Course Structure: Weeks 8—11

- Group project on an advanced topic
  - In week 7 you will be given the list of projects on offer and asked to give your ranked preferences
  - We will tell you your group and assigned project topic in week 8
  - Working with your group, you need to prepare a report and a presentation
  - You will get 2 meetings with your project supervisor in weeks 9 and 10
- The report – deadline 5pm 2nd May
  - 45% of final mark
  - One 20-page report prepared by group working together
  - Marked by member of academic staff
  - Peer questionnaire – each member of group will be asked to rate the contribution of each other group member
  - Any member contributing more or less than 20% of the average will have their individual mark adjusted pro-rata