COCKCROFT INSTITUTE

Introduction to RF
(Louise Cowie)

January 2026

The assessment is due on 16th February. Answer **ALL** questions
Time Guidance: This assessment should take around 4 hours of work.

Postgraduates may use electronic calculators, computers
and other aids (e.g. Internet) to assist in their completion of this assessment.

Please ensure you have the latest versions of the lecture slides from OneDrive as mistakes have been corrected since the lectures were given.

1. The UK XFEL design has L-band (1.3 GHz) superconducting cavities. Explain why L-band superconducting might be chosen over normal conducting cavities or different frequency superconducting cavities. Discuss the advantages and disadvantages of each for this accelerator.

[10 marks]

2. Consider a 2.9985 GHz 9-cell standing wave RF structure, into which is injected a 100 MeV electron bunch. The on-axis longitudinal electric field E_z for half a cell (between 0 and $L/2$) is described by

$$E_z(z) = E_0 \left(1 - \exp\left(\frac{-2L + 4z}{a\pi}\right)\right)$$

where the aperture size a is 6 mm, and E_0 is 30 MV/m, and the other half of the cell can be found by symmetry about 0. Find

a) The length of each cell L to give maximum acceleration

b) The energy of the electrons after the structure for on crest particles

c) The energy of the electrons after the structure for particles 20 degrees off crest

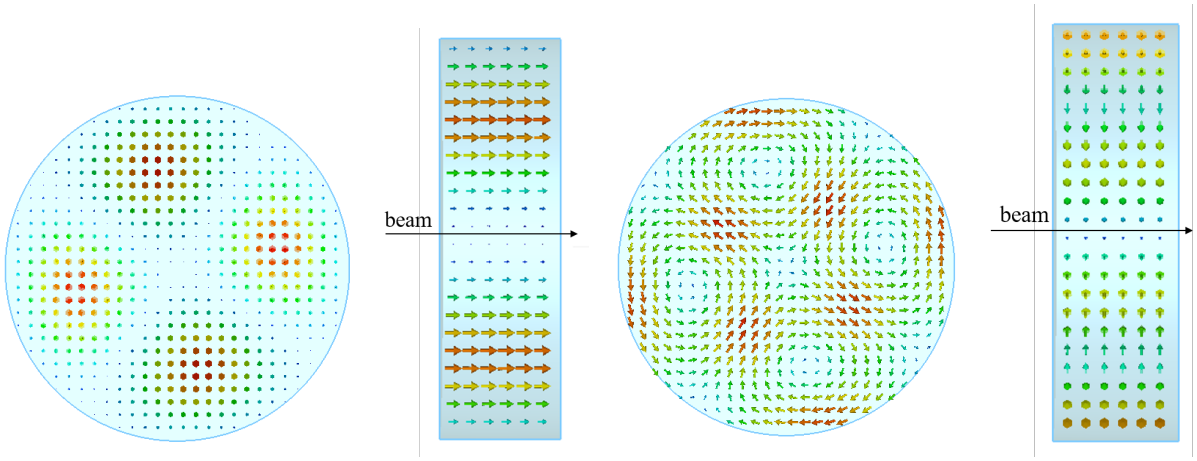
[10 marks]

3. a) What is the name of the mode below?

b) What is it's frequency if the pillbox has radius 100 mm?

c) Can the mode kick the beam if the beam is on axis as in the picture?

d) Can the mode kick the beam if the beam is off axis?



E fields H fields

[10 marks]

4. If a cavity has a shunt impedance of 200 MΩ and has an accelerating voltage of 100 MV, calculate the power required to accelerate a beam current of 10 mA.

[5 marks]

5. A 1.3 GHz cavity has an ohmic Q factor of 10^{10}, an external Q factor of 10^6 and is driven by a 12 kW RF source. What is the stored energy in the cavity, and the reflected power for a steady-state situation?

[5 marks]

6. If the surface resistance R_S of a 500 MHz niobium RF cavity is 6 nΩ at 2 K, what is the R_S at 4 K?

[5 marks]

7. Calculate the maximum surface magnetic field allowed to avoid damage from pulsed RF heating on a 12 GHz copper cavity, if the RF pulse duration is 1.5 μs.

[5 marks]

END OF EXAMINATION PAPER