Question 1 [11 marks]:

a) Explain why traditional charge-transport models used to describe crystalline semiconductors such as c-Si or GaAs are not generally valid for the semiconductors employed in thin-film transistors (TFTs). [2 marks]

b) State a type of measurement you could carry out to determine whether transport primarily occurs due to a band-like process or via some disordered process (such as multiple trapping and release or variable range hopping)? [1 mark]

c) The figure below shows mobility measured plotted as a function of $1000/T$ for a thin-film transistor with a log10 y-axis scale. The blue points are experimental data and the red line is a linear fit. The gradient of the fit is $m = -0.177$ K and the intercept is 20 cm$^2$/Vs. By assuming this data can be accurately described by multiple-trapping and release (MTR), determine the activation energy of this semiconductor. Give your answer in meV. [4 marks]

![Graph showing mobility vs. $1000/T$](image)

You will need:
- Boltzmann Constant $k_B = 1.38 \times 10^{-23}$ J/K.
- Fundamental unit of charge $e = 1.602 \times 10^{-19}$ C.

d) Consider a 2-dimensional material system which we can describe in terms of variable range hopping (VRH). The figure below shows the location of 20 available transport sites and the connectivity of each site at the onset of critical percolation. A list of positions of each connection in this first percolating cluster is provided as a csv file available to download here. **Important: This is a list of only the connections at critical percolation (not all possible connections!).** If the wavefunction overlap parameter in this system is $\alpha = 0.5\text{Å}^{-1}$, and the conductivity prefactor is $\sigma_0 = 50$ Scm$^{-1}$, use percolation theory to determine the conductivity ($\sigma$) of this film. Give your answer in Scm$^{-1}$ and assume the energetic offset between sites is zero for all hops. [4 marks]
Question 2 [7 marks]:
   a) Give one reason why we cannot use crystalline silicon for television backplanes.[1 mark]
   b) Explain why hydrogenated amorphous silicon (a-Si:H) is much more prevalent than simple non-hydrogenated amorphous silicon (a-Si) in commercial applications.[2 marks]
   c) By referring to the Multiple Trapping and Release model, explain how optical measurements can be used to infer the electronic properties of amorphous silicon.[2 marks]
   d) Provide 2 reasons why low-temperature polycrystalline silicon (LTPS) is not (currently) employed commercially for display backplanes.[2 marks]

Question 3 [7 marks]:
   a) Aluminum oxide is a wide-band gap insulating metal oxide, formed via ionic bonding. By assuming that all outer shells are filled / empty, determine the chemical formula of aluminum oxide and explain your reasoning. You will need to use the fact that aluminum (Al) is a Group 13 element and oxygen (O) is a Group 16 element.[2 marks]
   b) Provide one reason why the on/off ratio of TFTs formed of oxides such as ZnO or In$_2$O$_3$ are so high compared to silicon.[1 mark]
   c) Explain briefly why films of indium-gallium-zinc oxide (IGZO) are normally amorphous.[1 mark]
   d) Explain briefly why semiconductors that have transport states typically consisting of $s$-type orbitals are attractive for TFTs.[2 marks]
   e) Provide one reason why solution-processable metal oxide semiconductors are attractive for commercial applications.[1 mark]