Assignment 1: Unit-1 Review of Fundamental LLMs

History and Evolution of Language Models

1. Analyse the transition from **statistical language models** (like n-grams) to **neural language models** (like RNNs and LSTMs). What specific linguistic challenges (e.g., syntax, long-range dependencies, semantic understanding) were statistical models ill-equipped to handle, and how did the architecture of early neural networks provide a more effective solution?
2. The development of language models can be seen as a journey from "memorization" to "generalization." Discuss this statement by comparing at least three distinct milestones in language model history (e.g., n-grams, word2vec, Transformers). For each milestone, explain how it improved the model's ability to generalize beyond its training data.

Transformer Architecture and Self-Attention Mechanism

1. Imagine you are explaining the **self-attention mechanism** to a non-technical manager. Using a simple, concrete sentence as an example (e.g., "The cat sat on the mat, and it was happy."), describe step-by-step how self-attention would calculate the contextual meaning of the word "it." How does this process give Transformers an advantage over older models like LSTMs?
2. Beyond self-attention, the Transformer architecture includes other crucial components like **positional encodings** and **feed-forward networks**. Choose one of these components and argue for its importance. What would be the consequences for the model's performance and capabilities if this component were removed or poorly designed?

Pretraining vs. Fine-Tuning Paradigms

1. Critically evaluate the **pre-training/fine-tuning paradigm**. While it's highly effective, what are its potential drawbacks? Discuss significant challenges, such as "catastrophic forgetting" (where a model loses general knowledge during fine-tuning) or the risk of inheriting and amplifying biases from the pre-training data into specialized applications.
2. Consider two hypothetical scenarios: (A) a model with state-of-the-art pre-training but a small, noisy fine-tuning dataset, and (B) a model with mediocre pre-training but a large, high-quality fine-tuning dataset. Which scenario do you believe would likely result in a more reliable and effective specialized model? Justify your reasoning by discussing the distinct roles that pre-training and fine-tuning play in a model's final capabilities.

Scaling Laws and Model Efficiency

1. The "bigger is better" philosophy, driven by **scaling laws**, has dominated LLM research. Discuss the long-term sustainability of this approach. Analyse the trade-offs between continuing to scale models to astronomical sizes versus investing in research on data quality and algorithmic efficiency. Which path do you believe holds more promise for the future of AI?
2. You are the head of an AI startup with a limited computational budget. You cannot afford to train a massive, billion-parameter model from scratch. Describe a practical and efficient

strategy you would employ to develop a competitive, specialized language model for a niche industry (e.g., legal document analysis or medical chatbots). Your strategy should incorporate concepts like **transfer learning**, **model distillation**, or **quantization**.

Ethical Considerations in Large-Scale AI

1. Of the many ethical issues surrounding LLMs (bias, misinformation, privacy, etc.), which one do you consider the **single most urgent threat** to society? Write a persuasive argument defending your choice, explaining why it takes precedence over other ethical concerns and outlining the immediate, real-world harm it poses.
2. Design a set of **three core ethical guidelines** for a company developing a new public-facing generative AI. For each guideline, explain its importance and describe a specific, actionable process the company could implement to ensure the guideline is followed throughout the model's lifecycle, from data collection to deployment and ongoing monitoring.
