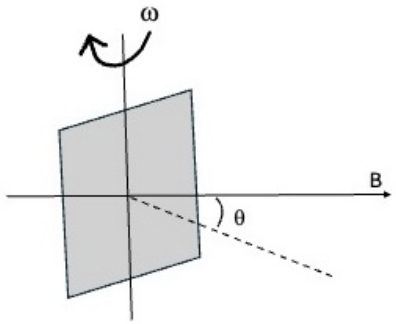
Physics 110B, Fall 2024, Midterm Exam

Please put a "box" around each of your final answers.

Problem 1

A coil of area A, resistence R, and self-inductance L is rotated about a vertical axis in the plane of the coil with constant angular velocity ω. There is a constant horizontal magnetic field B. See sketch below. At t=0, $\theta = 0$.
(a) Find the current as a function of time $I(t)$.
(b) Find the torque as a function of time $\tau(t)$ needed to maintain constant ω.
Hint: think about conservation of energy. Also, remember that the work done by a force is force times linear displacement, while the work done by a torque is torque times angular displacement.
To get credit for part (b), even if you cannot solve for $I(t)$, just derive a relationship between $\tau(t)$ and $I(t)$.



Problem 2

At $t = 0$ an emf is suddenly applied to a coil of inductance L_1. Next to this coil there is a second coil of inductance L_2, and let the mutual inductance between the two coils be M. As a result of the presence of the second coil, and the non-zero value of M, at $t = 0$ it will appear as if the first coil has an inductance L'. What is L'?
Hint: At $t = 0$ there is no current flowing anywhere, therefore there are no IR drops in any of the coils.

Problem 3

A parallel plate capacitor consists of two circular plates of radius a with vacuum between them. It is connected to a battery which maintains a constant voltage V between the plates. The plates are then slowly oscillated so that they remain parallel but their separation d is varied as $d = d_0 + d_1 \sin \omega t$.
(a) Find the magnetic field between the plates produced by the displacement current a radial distance r from the axis connecting the centers of the plate (for both $r < a$ and $r > a$).
(b) Same question, but for the case when the capacitor is first disconnected from the battery and then the plates are oscillated in the same way.

Problem 4

The electric field of a **wave** in vacuum is $\vec{E} = E_0 \exp[i(hz - \omega t) - kx]\hat{y}$.
(a) How are the real h, k and ω parameters related to each other?
(b) What is $\vec{B}$. You should leave your answer in complex form, and please do not bother with the extra algebra of eliminating one of h, k or ω using the result of part (a).