Essential Knowledge Questions used for Program Assessment

Below is a list of example Essential Knowledge Questions (EKQs) that will be used to test student knowledge regarding essential knowledge that physics faculty have determined as necessary for all physics B.S. graduates. Student performance will be used as date for the department's yearly program assessment. This list will be expanded as more EKQs are developed.

<u>Electromagnetism</u>

- Let's say that a student in PHSX 423 is asked to calculate the electric field for an infinite disc of charge, yielding $\mathrm{E} = \sigma/2\varepsilon_0$. The associated EKQ might ask, Your result should have revealed that $\mathrm{E} = \sigma/2\varepsilon_0$, show that the units of E are volts per meter., thereby testing the Essential Knowledge category – dimensional analysis.

- Imagine that a 1 cm thick plate of copper with no net electric charge is placed in a static, uniform electric field E with the field lines passing perpendicular to the plate's surface. Sketch the distribution of electric charge on the plate and state the net electric field at the surfaces and inside the plate.

- Write down the Poynting vector in terms of electric and magnetic fields. From that expression, determine the units of the Poynting vector.

- Can an electromagnetic wave propagate in a perfect conductor? Explain.

- Why is the sky blue?

- A conducting ring of radius *a* has resistance *R* and lies in the *xy* plane. An experimenter creates an oscillating magnetic field $\boldsymbol{B} = B_0 \cos{(\omega t)}\hat{z}$. Determine how much work the experimenter must do per cycle. Supposedly magnetic fields do no work. How is the work being done?

- Waves in some material follow the dispersion relation $\omega = ck - bk^2$, where ω is the angular frequency, k is the wave number, and *c* and *b* are positive constants. Determine the wave number at which the group velocity vanishes. Determine the wave number at which the phase velocity vanishes.

- A long metal cylinder is placed in an otherwise uniform electric field $\mathbf{E_0} = \mathbf{E_0 x}.$ Find the electric field inside and outside the cylinder.

- A circular loop of radius *a* carrying a steady current is placed in the *xy* plane, far from the origin, and the loop makes an angle Θ with the *xy* plane. Find the torque on the loop by a magnetized cylinder at the origin.

- The magnetic field outside a sphere of uniform magnetization is known to be a dipole field; sketch this field.

- A dielectric sphere carries a uniform free volume charge ρ_0. Plot *D* and *E* as a function of *r*, or distance to the center of the sphere.

- The electric field inside a sphere of uniform polarization **P** is found to be $\boldsymbol{E}_{in} = -\boldsymbol{P}/3\epsilon_0$. Use dimensional analysis to show that the expression in the RHS does have the units of electric field.

Thermodynamics and Statistical Physics

- System A has two possible energy levels and System B has 3. The two systems are coupled through thermal conduction. What is the entropy of the entire system.

- Sketch the specific heat versus inverse temperature for a two-level system.

- Why does the temperature of the atmosphere decrease with height (on average)?

- A particle scatters with target particles in Medium A. In Medium B, both the target density and the cross section are twice their values of Medium A. How do the mean-free-paths compare in the two media?

- A gas (not necessarily ideal), initially in equilibrium at one atm and 300K, is compressed to half its initial volume over one second. There is no flow of heat. Can we regard the system as remaining close to equilibrium during its compression?

- Is the heat capacity at constant pressure for a substance larger or smaller than the heat capacity at constant volume? Explain. Do not assume the substance is an ideal gas.

- Using energy considerations, explain why most gases cool upon free expansion.

- Sketch the velocity distribution for an ideal (classical) gas, that is, the probability a particle in the gas has speed *v*, versus *v*. Include curves for high and low temperature.

Quantum Mechanics

Classical Mechanics

- A particle of mass *m* moves in the *1-d* potential: $V(x) = ax + c/x$, where *a* and *c* are positive constants. Determine the frequency of small oscillations about the minimum in the potential.

- A particle of mass *m* moves in the *1-d* potential: $V(x) = ax + c/x$, where *a* and *c* are positive constants. The particle is also subject to a damping force $-b\dot{x}$, where *b* is a constant. How could we choose the values of *a* and *c* that will make the particle damp to equilibrium as fast as possible? Extra Credit: derive your result from the equation of motion.

Mathematical Physics

- Sketch $e^{-x}\sin(x)$.

- A wire carries a current pulse of duration Δt. What is the approximate width of the pulse in frequency space?

- Find the eigenvalues and eigenvectors of the matrix [(0, 1), (-2, -3)].

- Find the point on $2x + 3y + z - 11 = 0$ for which $4x2 + y2 + z2$ is a minimum.

Electronics