**Some sample questions in the new Preliminary Examination format** 29 May 2009

1. A point mass $m$ slides frictionlessly on the inside of a vertical circular track of radius $R$. The speed of the mass at the bottom of the track is $v_0$.
   a) Assuming that the mass makes it to the top of the track, what is its speed at the top?
   b) What is the minimum value of $v_0$ which assures that the mass will actually reach the top of the circle? (Careful: If the "speed at the top" is 0, the mass will have lost contact with the track before it gets to the top. Let $v_{top}$ be the speed at the top, and consider the forces on the mass and its acceleration at the top of the circle.)

2. Write Maxwell's equations in integral form, and define the quantities that appear in them.

3. A mass $M$ is suspended from a massless rigid rod of length $L$ and swings as a simple pendulum. Let $\theta$ be the angle between the rod and the vertical. In terms of the given quantities, write
   a) the kinetic energy of the pendulum.
   b) the potential energy of the pendulum.
   c) the Lagrangian of the system.
   d) the Lagrange equation of motion for the variable $\theta$.

4. In the Bohr model of the hydrogen atom, an electron (mass $m$, charge $-e$) orbits an infinitely massive fixed proton of charge $+e$ in a circular path of radius $r$, and the angular momentum $l$ of the electron is quantized in integer multiples of Planck's constant $\hbar$ ($l = n\hbar$).
   a) Express the velocity of the electron in terms of $m$, $r$, $\hbar$ and $n$.
   b) Noting that the centripetal acceleration of the electron is due to the Coulomb attraction of the proton, find the radius of the circular orbit in terms of $m$, $r$, $\hbar$ and $n$.
   c) Find the total energy of the electron in terms of $m$, $r$, $\hbar$ and $n$.

5. The first two stationary states of a given quantum mechanical system are described by the time-independent normalized wave functions $\psi_1(x)$ and $\psi_2(x)$, corresponding to energy eigenvalues $E_1$ and $E_2$ respectively.

   A given physical state consists of an equal mixture of these two states.
   b) In terms of the given quantities, write the form of the time-dependent wave function $\Psi(x,t)$ for this state.
   c) Write the probability density corresponding to this wave function, and find the frequency of its time dependence.

6. a) What are Einstein's two postulates of special relativity?
   b) Event 1 occurs at position $x_1$ and time $t_1$, and event 2 occurs at position $x_2$ and time $t_2$, both as measured in the $xyz$ reference frame. An observer (Sam) is moving at velocity $u$ in the $+x$ direction. What is the time interval between the two events as seen in Sam's reference frame? Define all symbols which appear in your answer.