11. *Electricity and Magnetism* (Fall 2002)
Describe how you would *measure* the following physical quantities:

(a) An electrostatic field $\mathbf{E}$.

(b) A vector potential $\mathbf{A}$ defined by $\mathbf{B} = \nabla \times \mathbf{A}$ in the gauge $\nabla \cdot \mathbf{A} = 0$.

(c) The charge of an electron assuming its mass is known.

(d) The speed of light of electromagnetic waves.

(e) The electrical conductivity of a flame.

(f) The direction of wave propagation of a plane electromagnetic wave.

Please describe the approach and method as realistically as possible.

a. Watch the acceleration of a charged dust particle in vacuum with known mass and charge. Then use $\vec{F} = q\vec{E}$.

b. Use the Aharanov-Bohm effect by observing the shift in a dual slit interference pattern as the apparatus is moved through the $\vec{A}$ field.

c. The Milikan oil Drop experiment or use the cyclotron radius in a known magnetic field:
$F_c = qvB = mv^2/r \Rightarrow q = \frac{mv}{Br}$ where v is the initial velocity at insertion.

d. Use laboratory-scale microwaves in a resonant cavity with variable length to find the first fundamental mode and use $c = f\lambda$ where $\lambda = \frac{2L}{n}$ and $n \to 1$.

e. Flames are considered to be plasmas, so we can approximate them to be a metal and use the formula for the index of refraction of a metal $n^2 = 1 + \frac{\sigma/\epsilon_0}{i\omega(1+i\omega\tau)}$ $\tau = \frac{m\sigma}{Nq^2}$ and solve for σ, given n determined by optical means.

f. Use a rotatable photodetector plate that is smaller than the cross section of the plane wave and rotate it to find the maximum current output. In this position, the plane wave's direction of propagation will be normal to the surface because the intercepted flux is maximized.