Physics 224 **Fall 2002**

Discoveries and Inventions of Modern Physics **due 11:00 am Tuesday Nov. 19**

PROBLEM SET 7

November 14 Colloquium: "Fluorescence correlation spectroscopy in living cells: detection of single protein molecules and of internal protein dynamics"

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3:30 pm, 101 Rowland Hall

1. **AC Josephson Effect** When a static DC voltage V is applied across a Josephson junction, an AC current results. To see how this comes about, notice that an electron pair experiences a potential energy difference qV on passing across the junction, where $q = -2e$. We can say that a pair on one side is at potential $-eV$ and a pair on the other side is at $+eV$. Thus the equations of motion become

$$i\hbar\frac{\partial\psi_1}{\partial t} = \hbar T\psi_2 - eV\psi_1 \qquad i\hbar\frac{\partial\psi_2}{\partial t} = \hbar T\psi_1 + eV\psi_2 \tag{1}$$

   where ψ_1 is the superconducting order parameter on side 1:

$$\psi_1 = \sqrt{n_1}e^{i\theta_1} \tag{2}$$

   n_1 is the density of superconducting pairs on side 1. Similarly

$$\psi_2 = \sqrt{n_2}e^{i\theta_2} \tag{3}$$

   Assume that the superconductors are identical. Find the current density J as a function of time and of the phase difference $\delta(0)$. $\delta(0) = \theta_2 - \theta_1$ is the phase difference at $V = 0$. What is the angular frequency ω at which the current oscillates when a voltage V is applied?

2. Eisberg and Resnick Problem 13.18.

3. Eisberg and Resnick Problem 13.24.

4. Eisberg and Resnick Problem 13.30 (n-p-n transistor).