PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part C, 9 January 2001, 09:00 - 12:00

C1. Consider a one-dimensional simple harmonic oscillator described by a Hamiltonian

$$\hat{\mathcal{H}}_0 = \frac{\hat{p}^2}{2m} + \frac{1}{2}\, m\, \omega^2\, \hat{x}^2 \quad ,$$

with eigenstates $|\phi_n\rangle$ and energy eigenvalues $E_n = (n + \frac{1}{2})\hbar\omega$. A time dependent perturbation of the form $\hat{W}(t) = \gamma \hat{x}^2$ for $0 \leq t \leq \tau$ and $\hat{W}(t) = 0$ otherwise, is applied to the oscillator. Here γ is a constant and $\gamma \ll \quad m\omega^2$.

(a) (4 points) To first order, calculate the transition probability from the ground state to the first excited state.

(b) (4 points) To first order, calculate the transition probability from the ground state to the second excited state.

(c) (2 points) Assume the oscillator is initially in the third excited state. What final states have non-zero transition probability?

C2. (a) (2 points) The half-life, $\tau_{1/2}$, of ^{235}U is 7.04×10^8 y (y means years), and $\tau_{1/2}$ of ^{238}U is 4.47×10^9 y. Currently, the Earth's crust consists of naturally occurring U which is 99.27% ^{238}U and 0.72% ^{235}U. If the approximate age of the Earth is 4.5×10^9 y, what was the abundance of ^{235}U relative to ^{238}U when the Earth was formed? Ignore production of either ^{235}U or ^{238}U from other nuclides.

(b) (2 points) Using the data given in the Table, what is the energy (in MeV) released by the α-decay of ^{235}U?

Element	Atomic Mass (amu)
^{4}He	4.002602
^{235}U	235.043924
^{231}Th	231.036299

amu $\equiv$ atomic mass unit and 1 amu = 931.50 MeV/c^2

(c) (6 points) What fraction of the decay energy from $^{235}\text{U} \rightarrow \alpha + {}^{231}\text{Th}$ is carried by the α particle?

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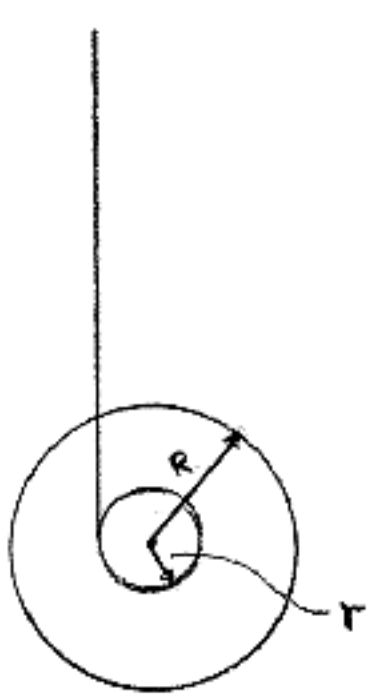
C3. A yo-yo consists of two disks of mass M each and radius R connected by a shaft of mass m and radius $r < R$. A weightless string is wrapped around the shaft.

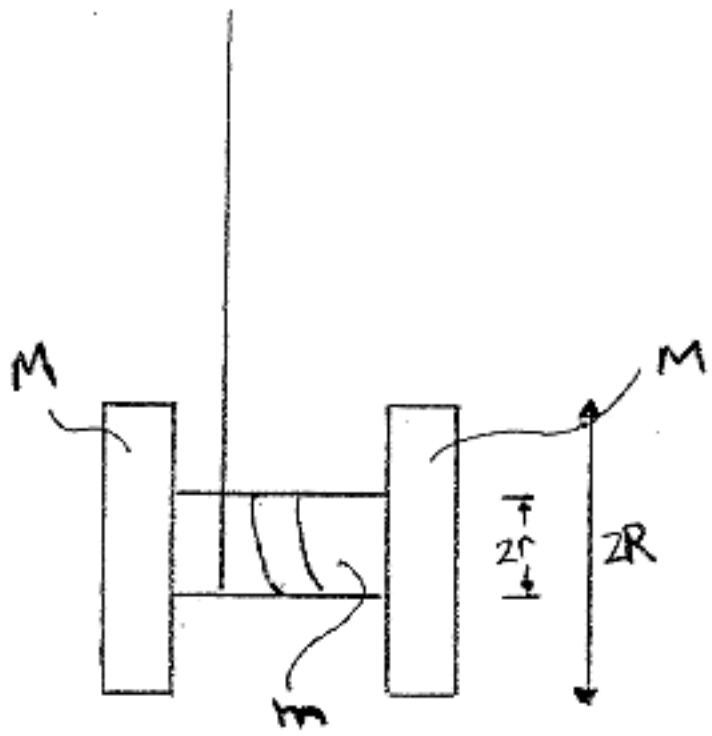
(a) (4 points) The free end of the string is held vertical and stationary in the Earth's gravitational field. Find the motion of the yo-yo's center of mass.

(b) (3 points) The free end is moved so as to keep the yo-yo's center of mass stationary. What is the acceleration of the free end of the string and the angular acceleration of the yo-yo?

(c) (3 points) The yo-yo is transported to empty space with no gravitational field. A force F is applied to the free end of the string. Give the acceleration of the center of mass, the yo-yo's angular rotation, and the acceleration of the free end of the string.



cross-section
A



cross-section
B