1. (20 points) The nuclear physics division at Argonne National Laboratory is building facility based on strong ^{252}Cf sources. The first source delivered for testing had a strength of 2.2 mCi on December 7th, 2008. This isotope has a 3% spontaneous fission branch and the remainder goes by alpha decay to the ground state (81.5%) and the first excited state at 43 keV (15.5%) of ^{248}Cm. A ^{252}Cf source also emits 3.8 neutrons and 9.7 gamma rays per fission. The ANL facility will collect the fission fragments from the source in gas and separate out specific fission products for study. The atomic number of californium is 98 and the half-life of this isotope is 2.64 years.

   (a) (5 pts.) What will be the rate of alpha emission from the 2.2 mCi source in Bq on July 4th, 2009?

   (b) (5 pts.) The facility eventually plans to operate with a ^{252}Cf source strength of 1 Ci, what is the mass in grams of this source?

   (c) (5 pts.) What will be the areal density of a 1 Ci ^{252}Cf source if the mass is evenly distributed in a 1.9 cm diameter circle?

   (d) (5 pts.) What is the rate of neutron emission from a 1 Ci ^{252}Cf source?

2. Provide concise written answers to the following four questions.

   (a) (5 points) Explain why gas-filled proportional chambers tend to be constructed with a very thin central wire (perhaps 40μm in diameter) and often have a cylindrical geometry.

   (b) (5 points) Which fill gas would you expect to give a larger gain in a gas proportional counter, pure helium or a mixture of helium and a small amount of argon, all other things being equal? Explain your answer.

   (c) (5 points) A Geiger counter is closely related to a gas-filled proportional counter and both can be operated with the Ar/Methane mixture gas mixture called P-10. What is the role of the methane in the operation of a Geiger counter?

   (d) (5 points) The so-called ion chambers used with the S800 and Sweeper Magnet at the NSCL are really proportional chambers. Explain why the filling gas (the active ingredient) in these devices has to be flowed through the chamber to ensure reproducible operation.

3. (20 points) The lowest, equilibrium pressure of a certain chamber that is pumped by a turbo pump with an effective speed of 250 ℓ/s is 2.5x10^{-7} mbar. A seal on the chamber was subsequently changed by a novice graduate student and the chamber would only go down to a new equilibrium pressure of 5x10^{-5} mbar with everything else the same. The post-doc supervising the work decides that the seal must be bad, make an estimate of the area of the orifice that corresponds to this leak.

– continue –

4. (10 points) Given the attached spec-sheet for a Hamamatsu R1306 photomultiplier tube, what is the value of δ for this tube? Assume that amplification only occurs at the dynodes.

5. The following questions refer to a fully depleted silicon detector that is 300 μm thick that is made from n-type silicon with a resistivity of 10k Ω-cm.

   (a) (10 points) Make an estimate of the maximum collection time in seconds for the holes in this detector if the bias is sufficient to fully saturate the hole velocity.

   (b) (10 points) What are the majority current carriers in this material and make an estimate of the their density in this material.

   (c) (10 points) Make an estimate of the bias voltage necessary to fully deplete this detector.

   (d) (BONUS 10 points) What is the maximum resolution that would be obtained with this detector for the signal from a 6.00 MeV alpha particle?

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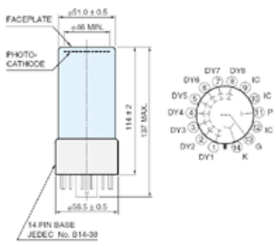
Part Number	Size [mm]
R1306	51

51mm head on PMT for the visible range. suitable for scintillation counting

Key Specifications

Part Number	R1306
Type	Head on
Size	51mm
ActiveDia/L	46mm
Min λ	300nm
Max λ	650nm
Peak Sens.	420nm
Cathode Radiant Sensitivity	95mA/W
Window	Borosilicate
Cathode Type	Bialkali
Cathode Luminous Sensitivity	110mA/lm
Cathode Blue Sensitivity Index	12
Red White Ratio	-
Anode Luminous Sensitivity	30A/lm
Gain	2.7E+05
Dark Current after 30 min.	2nA
Rise Time	7ns
Transit Time	60ns
Number of Dynodes	8
Applied Voltage	1000V
Multi Anode	N
Notes	For visible range and scintillation counting. electron transit time 60ns
Magnetic Shield	E989-05
Socket Bare	E678-14V
Socket + bleeder assy.	E1198-05 E1198-20
Power Supply	C3830 C4720 C4710
Amplifier	C7319 C6438 C5594 M7279 M8879

Drawing



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