CEM-988 Exam 2 **Take Home** 100 points
Winter/2oo9 Due: 30 Apr 2oo9 at 9:00am

1. (10 points) The NSCL has a ^{207}Bi source that is used primarily for gamma ray calibrations but it also can be used as an electron source.
    (a) (5 pts.) What is the decay mode and half-life of this source and what are the energies of the three strongest gamma-ray transitions?
    (b) (5 pts.) How are the electrons produced in this source? Are the electrons monoenergetic or do they have a continuous distribution and what is the energy of the most intense electron (or electron group)

2. (10 points) Three events that corresponded to ^{40}Mg were observed during the search for the neutron drip-line during an experiment that lasted 11 days at the NSCL in 2007. The first event was observed after 5 days of running, the second was observed 1 hour later, and the third was observed on the 8th day. This distribution in time of events was thought to be unusual. What is the probability that the second event was observed only one hour after the first event?

3. (10 points) Make an estimate of the lowest, equilibrium pressure of an aluminum chamber (unbaked or "fresh" aluminum) that is pumped by a turbo pump with an effective speed of 250 ℓ/s after one hour of pumping. The chamber is cylindrical and has a diameter of 1.30 meters but is only 40 cm tall. The pump is mounted vertically, upside down, at the top of the chamber and can be seen in the N4 vault at the NSCL.

4. Provide concise written answers to the following four questions related to PMT's.
    (a) (5 points) What is the difference between an "active" and a "passive" base for a a photomultiplier tube? What role does the difference play during operation?
    (b) (5 points) Give a simple definition of the quantum efficiency of a photomultiplier tube, its typical value, and what role does it play in determining the overall resolution of a signal from a scintillator.
    (c) (5 points) What is the ratio of signal output from a ten-stage PMT that has a dynode gain of 5.1 to that from a twelve-stage PMT with a dynode gain of 4.7?
    (d) (5 points) Give a simple reason why various techniques have been developed for scintillators that emit uv light to shift the wavelength of that light into the visible region.

– continue –

5. Provide concise written answers to the following two questions related to germanium detectors.
   (a) (5 points) Clearly describe any trade-offs of detector properties for the end-cap detector geometry compared to those with a true-coaxial detector geometry.
   (b) (5 points) The SeGA detectors in use at the NSCL have a photopeak effficiency of 75%. What is the expected counting rate for the 0.662 MeV peak from a 10μCi ^{137}Cs point source at a distance of 50 cm from one of these detectors?

6. The Low-Energy Neutron Detector Array (LENDA) is being constructed to detect neutrons emitted in direct reactions in coincidence with the S800 spectrometer. The device is made up from a series of long, thin plastic scintillaor (BC-408) bars that are 30x4.5x2.5 cm^3 and will be placed 1 m from the target. A Hamamatsu H6410 photomultiplier is attached to each of the two 2.5x4.5 cm^2 faces of this orthorhombic solid. The neutrons enter the bars perpendicular to the 2.5 cm face and can travel a maximum length of 4.5 cm in the plastic.
   (a) (10 points) What is the primary mechanism for neutron interactions in this scintillator and what is the maximum amount of energy that a 1.5 MeV neutron can deposit in this plastic scintillator if it only undergoes one interaction?
   (b) (10 points) Estimate the effective linear attenuation coefficient for the emitted light in a working detector if the measured amount of light reaching one of the PMT's is 3.0 times larger if the source is 1.0 cm form the end compared to when the source is 29.0 cm from that end of the bar.
   (c) (10 points) Estimate the number of photoelectrons generated in one PMT when 1.00 MeV is deposited at the midpoint of the plastic bar.
   (d) (10 points) What is the value of δ for this PMT and what is the signal size in coulombs at the anode when 1.00 MeV is deposited at the midpoint of the plastic bar?

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Appendix C.2 Outgassing Rates of Unbaked Metals[1]

Material	q_1 (10^{-7} Pa-m/s)	α_1	q_{10} (10^{-7} Pa-m/s)	α_{10}
Aluminum (fresh) [a]	84.0	1.0	8.0	1.0
Aluminum (degassed 24 h) [a]	55.2	3.2	4.08	0.9
Aluminum (3 h in air) [a]	88.6	1.9	6.33	0.9
Aluminum (fresh) [a]	82.6	1.0	4.33	0.9
Aluminum (anodized 2-μm pores) [a]	3679.0	0.9	429.0	0.9
Aluminum (bright-rolled) [b]	–	–	100.0	1.0
Duraluminum [b]	2266.0	0.75	467.0	0.75
Brass (wave guide) [b]	5332.0	2.0	133.0	1.2
Copper (fresh) [a]	533.0	1.0	55.3	1.0
Copper (mechanically polished) [a]	46.7	1.0	4.75	1.0
Copper, OHFC (fresh) [a]	251.0	1.3	16.8	1.3
Copper, OHFC (mechanically polished) [a]	25.0	1.1	2.17	1.1
Copper, OHFC (20°C) [c]	–	–	0.408	–
Chrome (0.5%)–Copper, OFE (99.5%) [c]	–	–	0.102	–
Gold (wire fresh) [a]	2105.0	2.1	6.8	1.0
Mild steel [b]	7200.0	1.0	667.0	1.0
Mild steel (slightly rusty) [b]	8000.0	3.1	173.0	1.0
Mild steel (chromium-plated polished) [b]	133.0	1.0	12.0	–
Mild steel (aluminum spray coated) [b]	800.0	0.75	133.0	0.75
Steel (chromium-plated fresh) [a]	94.0	1.0	7.7	1.0
Steel (chromium-plated polished) [a]	121.0	1.0	10.7	1.0
Steel (nickel-plated fresh) [a]	56.5	0.9	6.6	0.9
Steel (nickel-plated) [a]	368.0	1.1	3.11	1.1
Steel (chemically nickel-plated fresh) [a]	111.0	1.0	9.4	1.0
Steel (chemically nickel-plated polished) [a]	69.6	1.0	6.13	1.0
Steel (descaled) [a]	4093.0	0.6	3933.0	0.7
Molybdenum [a]	69.0	1.0	4.89	1.0
Stainless steel EN58B (AISI 321) [b]	–	–	19.0	1.6
Stainless steel 19/9/1-electropolished [d]	–	–	2.7	–
-vapor degreased [d]	–	–	1.3	–
-Diversey cleaned [d]	–	–	4.0	–
Stainless steel [b]	2333.0	1.1	280.0	0.75
Stainless steel [b]	1200.0	0.7	267.0	0.75
Stainless steel ICN 472 (fresh) [a]	180.0	0.9	19.6	0.9
Stainless steel ICN 472 (sanded) [a]	110.0	1.2	13.9	0.8
Stainless steel NS22S (mechanically polished) [a]	22.8	0.5	6.1	0.7
Stainless steel NS22S (electropolished) [a]	57.0	1.0	5.7	1.0
Stainless steel [a]	192.0	1.3	18.0	1.9
Zinc [a]	2946.0	1.4	429.0	0.8
Titanium [a]	150.0	0.6	24.5	1.1
Titanium [a]	53.0	1.0	4.91	1.0

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[1] $q_n = qt^{-\alpha_n}$, where n is in hours. See Fig. 4.6 for a detailed explanation.

[a] A. Schram, *Le Vide*, No. 103, 55 (1963),

[b] B. B. Dayton, *Trans. 6th Natl. Vac. Symp. (1959)*, Pergamon Press, New York, 1960, p. 101,

[c] Y. Koyatsu, H. Miki, and F. Watanabe, *Vacuum*, **47**, 709 (1996),

[c] R. S. Barton and R. P. Govier, *Proc. 4th Int. Vac. Congr. (1968)*, Institute of Physics and the Physical Society, London, 1969, p. 775, and *Vacuum*, **20**, 1 (1970).