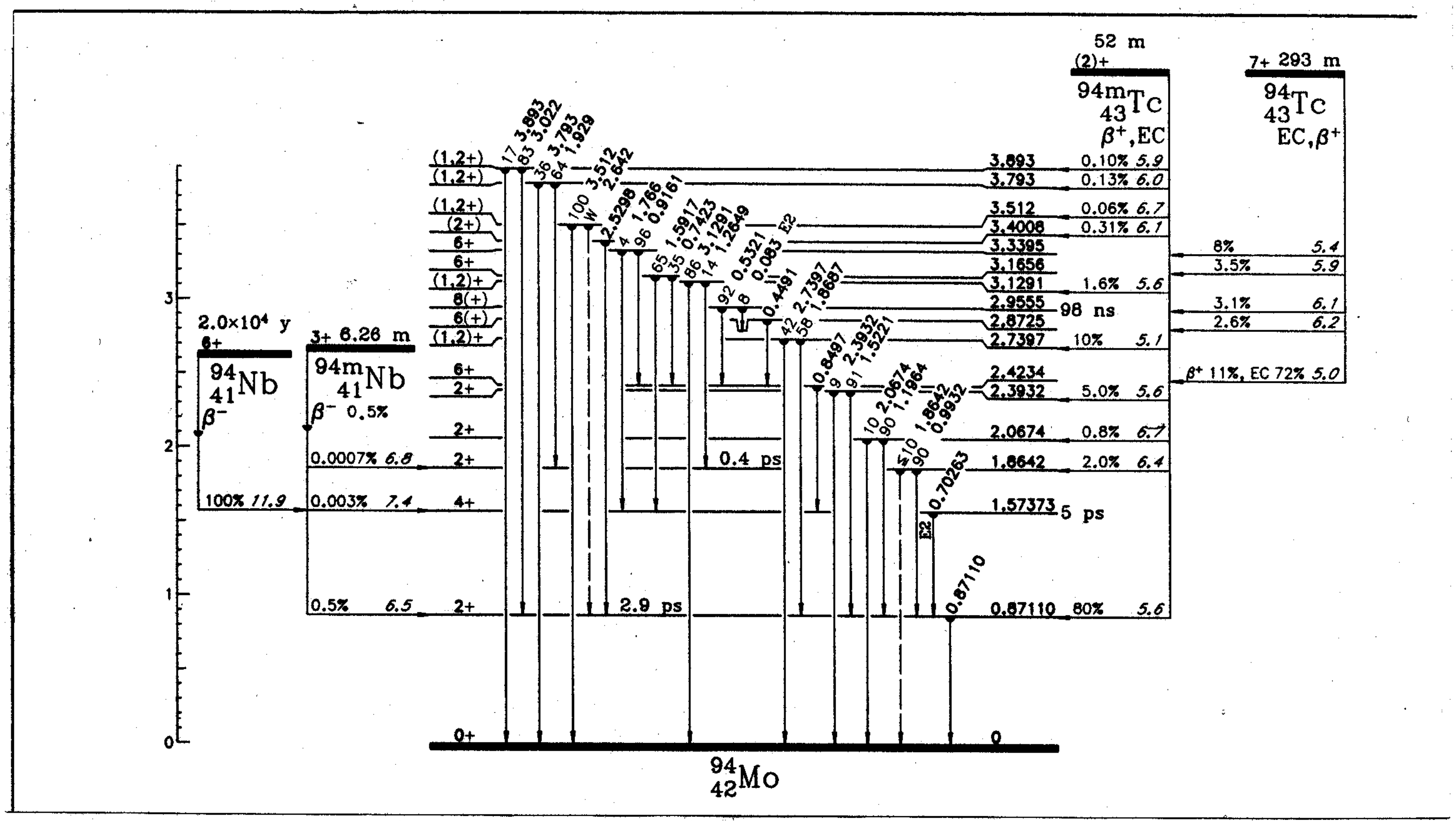
CEM-987 / PHY-905 Fall/2oo2

Exam 1, 8 October 2oo2

1. (20 points) A source of the nuclide ^{94}Nb was prepared by irradiation of a 10.0 gram foil of pure niobium metal with thermal neutrons in a reactor. The sample was irradiated with a flux of 10^{12} neutrons/sec/cm^2 for a period of 6.0 hours. Natural niobium is monoisotopic and the thermal neutron cross section for ^{93}Nb is 20 mb. Some information on the decay of ^{94}Nb from the Table of Isotopes, 8th Ed. is shown in the figure below.
   - (a) What is the activity (Ci) of the source after at the end of bombardment?
   - (b) What is the specific activity of this source at the end of bombardment?
   - (c) Indicate the type and energy of the three most prominent primary radiations from this source.
   - (d) Give one reason why you should try to locate and borrow a ^{94}Nb before you decide to create your own source in a reactor.



2. (10 points) Part of the first results from the Sudbury Neutrino Observatory (SNO) that were presented at the APS meeting in April, 2oo2, was the observation of 1968 charged-current neutrino events in 306.4 days of operation. One result from their work is that "neutrinos change flavor or oscillate" at the 5.3σ level.
   - (a) What is the probability that no events were observed on any given day during this run?
   - (b) What is the probability that "neutrinos don't oscillate"?

3. (10 points) Estimate the pulse height of the voltage signal from a cylindrical proportional counter with the following characteristics: 10μm radius anode, 2.54 cm cathode, P-5 (Ar 95%, CH_4 5%) filling gas at 1 atm, 1500 V bias, and detector capacitance 10.0 pF, and one primary ion-pair.

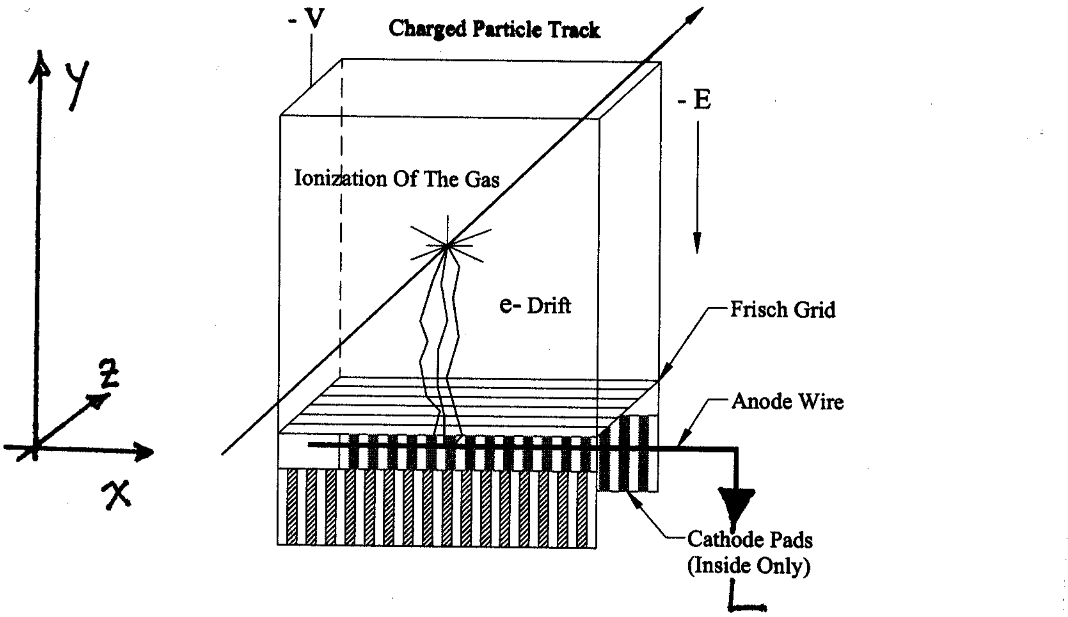
4. (15 points) On page 224 of the text, Knoll states that normal organic scintillators are significantly degraded after receiving doses of 10^3 Gy from gamma rays. In typical experiments, the scintillator at the focal plane of the A1900 is used to stop ions that deposit 1 GeV per particle. How many particles will it take to deliver a dose of 10^3 Gy to the scintillator? Assume that the range of the particles is 5 mm and they are spread over an area of 1 cm^2.

5. (20 points) The figure below is a schematic representation of a Cathode Readout Drift Chamber (CRDC) used at the NSCL from the M.S. thesis of Chris Freigang. During one mode of operation with pure methane gas at 140 torr, the cathode is held at -2000 V, the Frisch Grid at +10 V and the anode at +850 V. The anode wire is 12.5μm in diameter and the dimensions of the chamber are 30 cm x 30 cm by 8.64 cm thick. The anode is in the center of a rectangular volume (30 x 8.62 x 8.62 cm^3) but for this question you can assume this volume is equivalent to a cylindrical volume with r=4.32 cm.

   (a) These devices are position sensitive in two dimensions, thus requiring at least two measurements. Explain how the measured quantities are converted into calculated x and y positions of the initial ionization. (Cf. axes on figure.)

   (b) What is the distance from the anode wire that the electron avalanche starts if the electron-avalanche requires a field of 1x10^6 V/m.

   (c) The experimenter would like to obtain an absolute position resolution of 100 μ in the "y" position when the particle crosses the middle of the chamber. Using information in the text make an estimate of the drift time and the required uncertainty in the time **that would be consistent** with this level of precision in position.



6. (20 points) A plastic scintillator (BC-400) with an area of 5 cm x 5 cm and a thickness of 5 mm was connected by an adiabatic rectangular 1.0 m long light guide to a 2" diameter PMT (Hamamatsu 1306). The scintillator is wrapped so that it transmits 80% of the photons to the light guide. The physical properties of the light guide match those of the scintillator (ρ, n, etc.). The PMT was operated at it's recommended voltage of 1000 V. The device was intended to detect 3 MeV beta particles that are minimum ionizing (2 (keV cm^2/mg) *ρ)

   (a) Estimate the number of photons created by the passage of one minimum ionizing β particle through the scintillator.

   (b) Estimate the number of photons that reach the photocathode for the passage of one β particle through the active thickness.

   (c) Calculate the quantum efficiency from the cathode radiant sensitivity (the peak wavelength is ~400 nm, cf. Fig. 8.7) of this PMT.

   (d) Estimate the anode charge in the pulse from one β particle.

Some Constants

h = 6.626x10^{-34} J s   c = 3x10^{8} m/s   e = 1.602x10^{-19} Coul.

Following page: tables of the Gaussian Function and it's integral.

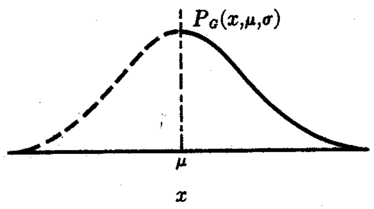


Table C-1 Gaussian probability distribution. The Gaussian or normal error distribution $P_G(x,\mu,\sigma)$ vs. $z = |x - \mu|/\sigma$

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.39894	.39892	.39886	.39876	.39862	.39844	.39822	.39797	.39767	.39733
0.1	.39695	.39654	.39608	.39559	.39505	.39448	.39387	.39322	.39253	.39181
0.2	.39104	.39024	.38940	.38853	.38762	.38667	.38568	.38466	.38361	.38251
0.3	.38139	.38023	.37903	.37780	.37654	.37524	.37391	.37255	.37115	.36973
0.4	.36827	.36678	.36526	.36371	.36213	.36053	.35889	.35723	.35553	.35381
0.5	.35207	.35029	.34849	.34667	.34482	.34294	.34105	.33912	.33718	.33521
0.6	.33322	.33121	.32918	.32713	.32506	.32297	.32086	.31874	.31659	.31443
0.7	.31225	.31006	.30785	.30563	.30339	.30114	.29887	.29659	.29431	.29200
0.8	.28969	.28737	.28504	.28269	.28034	.27799	.27562	.27324	.27086	.26848
0.9	.26609	.26369	.26129	.25888	.25647	.25406	.25164	.24923	.24681	.24439
1.0	.24197	.23955	.23713	.23471	.23230	.22988	.22747	.22506	.22266	.22025
1.1	.21785	.21546	.21307	.21069	.20831	.20594	.20357	.20122	.19887	.19652
1.2	.19419	.19186	.18955	.18724	.18494	.18265	.18038	.17811	.17585	.17361
1.3	.17137	.16915	.16694	.16475	.16256	.16039	.15823	.15609	.15395	.15184
1.4	.14973	.14764	.14557	.14351	.14147	.13944	.13742	.13543	.13344	.13148
1.5	.12952	.12759	.12567	.12377	.12189	.12002	.11816	.11633	.11451	.11271
1.6	.11093	.10916	.10741	.10568	.10397	.10227	.10059	.09893	.09729	.09567
1.7	.09406	.09247	.09090	.08934	.08780	.08629	.08478	.08330	.08184	.08039
1.8	.07896	.07755	.07615	.07477	.07342	.07207	.07075	.06944	.06815	.06688
1.9	.06562	.06439	.06316	.06196	.06077	.05960	.05845	.05731	.05619	.05509
2.0	.05400	.05293	.05187	.05083	.04981	.04880	.04781	.04683	.04587	.04492
2.1	.04399	.04307	.04217	.04129	.04041	.03956	.03871	.03788	.03707	.03627
2.2	.03548	.03471	.03395	.03320	.03247	.03175	.03104	.03034	.02966	.02899
2.3	.02833	.02769	.02705	.02643	.02582	.02522	.02464	.02406	.02350	.02294
2.4	.02240	.02187	.02135	.02083	.02033	.01984	.01936	.01889	.01843	.01798
2.5	.01753	.01710	.01667	.01626	.01585	.01545	.01506	.01468	.01431	.01394
2.6	.01359	.01324	.01290	.01256	.01224	.01192	.01160	.01130	.01100	.01071
2.7	.01042	.01015	.00987	.00961	.00935	.00910	.00885	.00861	.00837	.00814
2.8	.00792	.00770	.00749	.00728	.00707	.00688	.00668	.00649	.00631	.00613
2.9	.00595	.00578	.00562	.00546	.00530	.00514	.00500	.00485	.00471	.00457

	.00	.10	.20	.30	.40
3.0	.0044318	.0032668	.0023841	.0017226	.0012322
3.5	.00087269	.00061191	.00042479	.00029195	.00019866
4.0	.00013383	.000089264	.000058945	.000038536	.000024943
4.5	.000015984	.000010141	.0000063701	.0000039615	.0000024391
5.0	.0000014868	.00000089730	.00000053614	.00000031716	.00000018575
5.5	.00000010771	.00000006183	.00000003514	.00000001978	.00000001102

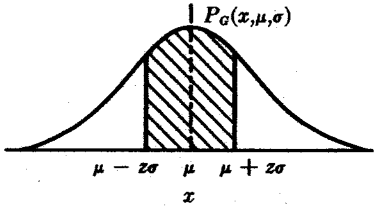


Table C-2 Integral of Gaussian distribution. The integral of the Gaussian probability distribution $A_G(x,\mu,\sigma)$ vs. $z = |x - \mu|/\sigma$

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0	.00798	.01596	.02393	.03191	.03988	.04784	.05581	.06376	.07171
0.1	.07966	.08759	.09552	.10343	.11134	.11924	.12712	.13499	.14285	.15069
0.2	.15852	.16633	.17413	.18191	.18967	.19741	.20514	.21284	.22052	.22818
0.3	.23582	.24344	.25103	.25860	.26614	.27366	.28115	.28862	.29605	.30346
0.4	.31084	.31819	.32551	.33280	.34006	.34729	.35448	.36164	.36877	.37587
0.5	.38292	.38995	.39694	.40389	.41080	.41768	.42452	.43132	.43809	.44481
0.6	.45149	.45814	.46474	.47131	.47783	.48431	.49075	.49714	.50350	.50981
0.7	.51607	.52230	.52847	.53461	.54070	.54674	.55274	.55870	.56461	.57047
0.8	.57629	.58206	.58778	.59346	.59909	.60467	.61021	.61570	.62114	.62653
0.9	.63188	.63718	.64243	.64763	.65278	.65789	.66294	.66795	.67291	.67783
1.0	.68269	.68750	.69227	.69699	.70166	.70628	.71085	.71538	.71985	.72428
1.1	.72866	.73300	.73728	.74152	.74571	.74985	.75395	.75799	.76199	.76595
1.2	.76985	.77371	.77753	.78130	.78502	.78869	.79232	.79591	.79945	.80294
1.3	.80639	.80980	.81316	.81647	.81975	.82298	.82616	.82930	.83240	.83546
1.4	.83848	.84145	.84438	.84727	.85012	.85293	.85570	.85843	.86112	.86377
1.5	.86638	.86895	.87148	.87397	.87643	.87885	.88123	.88358	.88588	.88816
1.6	.89039	.89259	.89476	.89689	.89898	.90105	.90308	.90507	.90703	.90896
1.7	.91086	.91272	.91456	.91636	.91813	.91987	.92158	.92326	.92491	.92654
1.8	.92813	.92969	.93123	.93274	.93422	.93568	.93711	.93851	.93988	.94123
1.9	.94256	.94386	.94513	.94638	.94761	.94882	.95000	.95115	.95229	.95340
2.0	.95449	.95556	.95661	.95764	.95864	.95963	.96059	.96154	.96247	.96338
2.1	.96426	.96513	.96599	.96682	.96764	.96844	.96922	.96999	.97074	.97147
2.2	.97219	.97289	.97358	.97425	.97490	.97555	.97617	.97679	.97739	.97797
2.3	.97855	.97911	.97965	.98019	.98071	.98122	.98172	.98221	.98268	.98315
2.4	.98360	.98404	.98448	.98490	.98531	.98571	.98610	.98648	.98686	.98722
2.5	.98758	.98792	.98826	.98859	.98891	.98922	.98953	.98983	.99012	.99040
2.6	.99067	.99094	.99120	.99146	.99171	.99195	.99218	.99241	.99264	.99285
2.7	.99306	.99327	.99347	.99366	.99385	.99404	.99422	.99439	.99456	.99473
2.8	.99489	.99504	.99520	.99534	.99549	.99563	.99576	.99589	.99602	.99615
2.9	.99627	.99638	.99650	.99661	.99672	.99682	.99692	.99702	.99712	.99721

	.00	.10	.20	.30	.40
3.0	.9973002	.9980648	.9986257	.99903315	.99932614
3.5	.99953474	.99968178	.99978440	.99985530	.999903805
4.0	.999936656	.999958684	.999973308	.999982920	.999989174
4.5	.9999932043	.9999957748	.9999973982	.9999984132	.99999904149
5.0	.99999942657	.99999966024	.99999980061	.99999988410	.99999993327
5.5	.99999996193	.99999997847	.99399998793	.99999999328	.99999999627