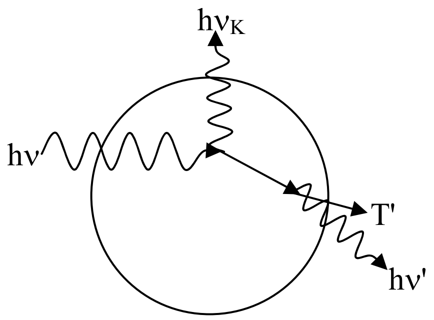
Compulsory task in FYSKJM4710

Interaction theory and dosimetry

a) Describe the general types of interactions that contribute to the collision stopping power, $(dT/\rho dx)_C$?
What is the maximum energy transferred from a 50 MeV proton to an electron in a hard collision?
Find the I and Z/A values of air and water from Appendix B.2. (Derive Z/A from $N_A Z/A$).
Calculate the total collision stopping power, $(dT/\rho dx)_C$ of 50 MeV protons in air and water.

b) In Appendix D.1 the electronic Klein-Nishina cross-sections are given.
Find from this table the K-N-values of the electronic cross-section, ${}_e\sigma$, and the electronic cross of energy-transfer, ${}_e\sigma_{tr}$, of 50 keV photons.
Calculate contribution of the Compton interaction to the mass attenuation coefficients, σ/ρ, and the mass energy-transfer coefficients, σ_{tr}/ρ, of 50 keV photons in air and water. Use the electron density ($N_A Z/A$) from Appendix B.2.
The total coefficients are: $(\mu/\rho)_{air} = 0.206$ cm^2/g and $(\mu_{tr}/\rho)_{air} = 0.0406$ cm^2/g
$(\mu/\rho)_{water} = 0.225$ cm^2/g and $(\mu_{tr}/\rho)_{water} = 0.0418$ cm^2/g
Calculate the fraction of the total coefficients that are due to Compton interaction, both attenuation and energy-transfer?
Why are the fractions due to Compton interaction of the mass energy-transfer coefficients, μ_{tr}/ρ, less than that of the mass attenuation coefficients, μ/ρ?

c) A photon enters a small volume of interest in which the interactions as shown occur:



Which process terminates the incoming photon?
What process is the origin of the photon of energy hν'?
Determine ε_{tr} *energy transferred*, ε^n_{tr} *net energy transferred* and ε *absorbed energy*. (No calculations should be done, express the answers by $h\nu$, $h\nu_K$, $h\nu'$ and T').

d) Why can the mass energy-absorption coefficient μ_{en}/ρ be approximated by μ_{tr}/ρ, when the photon energy is 50 keV and the medium is air or water?

Define exposure and how dose to air is derived from this parameter from photon radiation with charged particle equilibrium.

e) An air filed ionization chamber is placed in water. By use of an electrometer a charge of $Q = 50\ nC$ is measured during 2 minutes – the radiation is a 50 keV monoenergetic photon source (CPE may be assumed). The chamber has an air volume of $V = 0.65\ cm^3$, the air density is $\rho_{air} = 1.2\times10^{-3}\ g/cm^3$ and average energy per charge in air is $W/e = 33.97\ J/C$.

What is the exposure X in the ionization chamber?

What is the energy fluence of the photon field?

What is the absorbed dose in air?

What is the absorbed dose and dose rate in water?

f) Define the charge measurement in problem e) as M. From the definition of the calibration factor of absorbed dose in water, what is the calibration factor $N_{D,water}$ (in mGy/nC) at the current photon energy?

The same exposure is produced by 50 MeV protons. Use Bragg-Gray theory and the value of collision stopping power calculated in a) to estimate the energy fluence of the proton field?

What is the absorbed dose in water from the protons?

For this 50 MeV proton field, estimate the radiation quality correction k_Q, related to the calibration factor $N_{D,water}$ calculated from the 50 keV photons.

Required information:

APPENDIX D.1 Klein–Nishina Interaction Cross Sections for Free Electrons[a]

$h\nu$ (keV)	${}_e\sigma$ (cm^2/e)	${}_e\sigma_{sc}$ (cm^2/e)	${}_e\sigma_{tr}$ (cm^2/e)
1.0	0.6627 −24	0.6614 −24	0.1291 −26
1.5	0.6614 −24	0.6594 −24	0.1929 −26
2.0	0.6601 −24	0.6575 −24	0.2561 −26
3.0	0.6576 −24	0.6537 −24	0.3811 −26
4.0	0.6550 −24	0.6500 −24	0.5041 −26
5.0	0.6525 −24	0.6463 −24	0.6251 −26
6.0	0.6501 −24	0.6426 −24	0.7441 −26
8.0	0.6452 −24	0.6355 −24	0.9766 −26
10.0	0.6405 −24	0.6285 −24	0.1202 −25
15.0	0.6290 −24	0.6116 −24	0.1735 −25
20.0	0.6180 −24	0.5957 −24	0.2228 −25
30.0	0.5975 −24	0.5664 −24	0.3109 −25
40.0	0.5787 −24	0.5400 −24	0.3871 −25
50.0	0.5615 −24	0.5162 −24	0.4532 −25
60.0	0.5456 −24	0.4945 −24	0.5109 −25
80.0	0.5173 −24	0.4567 −24	0.6059 −25
100.0	0.4927 −24	0.4247 −24	0.6800 −25
150.0	0.4436 −24	0.3631 −24	0.8054 −25
200.0	0.4065 −24	0.3185 −24	0.8794 −25
300.0	0.3535 −24	0.2581 −24	0.9531 −25
400.0	0.3167 −24	0.2186 −24	0.9805 −25
500.0	0.2892 −24	0.1905 −24	0.9871 −25
600.0	0.2675 −24	0.1692 −24	0.9831 −25
662.0	0.2561 −24	0.1584 −24	0.9775 −25
800.0	0.2350 −24	0.1389 −24	0.9602 −25
(MeV)			
1.0	0.2112 −24	0.1183 −24	0.9294 −25
1.25	0.1888 −24	0.9997 −25	0.8885 −25
1.5	0.1716 −24	0.8670 −25	0.8488 −25
2.0	0.1464 −24	0.6867 −25	0.7769 −25
3.0	0.1151 −24	0.4865 −25	0.6644 −25
4.0	0.9597 −25	0.3772 −25	0.5825 −25
5.0	0.8287 −25	0.3083 −25	0.5204 −25
6.0	0.7323 −25	0.2607 −25	0.4716 −25
8.0	0.5988 −25	0.1993 −25	0.3995 −25
10.0	0.5099 −25	0.1613 −25	0.3485 −25
15.0	0.3771 −25	0.1094 −25	0.2678 −25
20.0	0.3025 −25	0.8271 −26	0.2198 −25
30.0	0.2200 −25	0.5563 −26	0.1644 −25
40.0	0.1746 −25	0.4191 −26	0.1327 −25
50.0	0.1457 −25	0.3362 −26	0.1121 −25
60.0	0.1254 −25	0.2807 −26	0.9736 −26
80.0	0.9882 −26	0.2110 −26	0.7772 −26
100.0	0.8199 −26	0.1690 −26	0.6508 −26

[a]Table provided by Patrick D. Higgins, personal communication, 1986.

Appendix B.2. Data Table for Compounds and Mixtures[a]

$N_A Z/A$

Material	Density (g/cm^3)[c]	Electron density (10^{23} e/g)	I (eV)[d]
A-150 plastic[b]	1.127	3.306	65.1
Adipose tissue (Fat, ICRP)[b]	0.92	3.363	63.2
Air[b]	1.205×10^{-3}	3.006	85.7
Bone, cortical (ICRP)[b]	1.85	3.139	106.4
Calcium fluoride, CaF_2	3.18	2.931	166
Carbon dioxide, CO_2	1.842×10^{-3}	3.010	85.0
Cesium iodide, CsI	4.51	2.503	553
Lithium fluoride, LiF	2.64	2.786	94.0
Lucite, $(C_5H_8O_2)_n$	1.19	3.248	74.0
Muscle, skeletal (ICRP)[b]	1.04	3.308	75.3
Mylar, $(C_{10}H_8O_4)_n$	1.40	3.134	78.7
Nylon, type 6 $(C_6H_{11}NO)_n$	1.14	3.299	63.9
Polycarbonate $(C_{16}H_{14}O_3)_n$	1.20	3.173	73.1
Polyethylene $(C_2H_4)_n$	0.94	3.435	57.4
Polyimide $(C_{22}H_{10}N_2O_5)$	1.42	3.087	79.6
Polypropylene $(C_3H_5)_n$	0.90	3.372	59.2
Polystyrene $(C_8H_8)_n$	1.06	3.238	68.7
Polyvinyl Chloride $(C_2H_3Cl)_n$	1.30	3.083	108.2
Pyrex (borosilicate glass)[b]	2.23	2.993	134
Silicon dioxide, SiO_2	2.32	3.007	139.2
Silver bromide, AgBr	6.47	2.629	487
Sodium iodide, NaI	3.67	2.571	452
Teflon, $(C_2F_4)_n$	2.20	2.890	99.1
TE gas (methane-based)[b]	1.064×10^{-3}	3.312	61.2
TE gas (propane-based)[b]	1.826×10^{-3}	3.314	59.5
TE liquid (no sucrose)[b]	1.070	3.313	74.2
Water, H_2O	0.9982	3.343	75.0

[a]Data from Berger and Seltzer (1983)
[b]See compositions in Appendix B.3
[c]Assuming $T = 20°C.$, $P = 1$ atm., and Charles' Law for gases applies.
[d]I is the mean excitation potential for stopping power, see Chapter 8.