IF YOU HAVE ANY PROBLEMS WITH THE MARKING OF TEST #2, WRITE A SHORT NOTE TO PROF. MCNEILL SAYING WHAT THE PROBLEM IS AND HAND THE NOTE WITH YOUR MARKED TEST TO EITHER APRIL SEELEY IN ROOM MP302 OR TERESA BAPTISTA IN ROOM MP301 BY THE END OF JANUARY 2002.

PHY 238Y - LIFE SCIENCES II

MID-TERM TEST #2 - JANUARY 15, 2002

TIME: 50 MINUTES

All four questions (Q1, Q2, Q3 and Q4) have approximately equal mark value, but may not be of equal difficulty.

Calculators may be used.

Constants and Formulae

$P(x,m) = m^x e^{-m}/x!$
Density of water = 10^3 kg/m^3
$N_{AV} = 6.0 \times 10^{23}$
0°C = 273 K
1 Gy = 1 J/kg
$\eta_{blood} = 2.084 \times 10^{-3}$ Pa s
$\eta_{water} = 1.005 \times 10^{-3}$ Pa s
1 litre = 10^{-3} m^3
$e = 1.6 \times 10^{-19}$ C
$m_e = 9.11 \times 10^{-31}$ kg
$\mu_0 = 4\pi \times 10^{-7}$ H/m (Permeability constant)

Density of blood = 1.06×10^3 kg/m^3
1 MeV = 1.6×10^{-13} J
$g = 9.8$ m s^{-2}
$\ln 2 = 0.693$
Sv = Gy × Q (or w_R)
$Q(w_R)$ gamma rays = 1
$Q(w_R)$ betas = 1
$Q(w_R)$ alphas = 20
$c = 3.0 \times 10^8$ ms^{-1}

$$I_\theta = a^2 \frac{\sin^2(\Delta/2)}{(\Delta/2)^2} \frac{\sin^2(N\delta/2)}{\sin^2(\delta/2)} \text{ with I for } \theta = 0 \text{ being } N^2a^2$$

A flux of 10^7 m^{-2}s^{-1} of 1 MeV gamma rays gives a dose rate of approx. 2.5 mr/hr

1. A radioactive source (4.7×10^5 Bq) is uniformly distributed in a 60 kg person. The source gives 5.4 MeV alphas and 0.7 MeV gamma rays (i.e. each disintegration gives both alphas and gammas).

(a) Calculate the initial dose rate and

(b) the initial dose equivalent rate

Dose Rate

$$\frac{(4.7 \times 10^5 \text{ Bq})(5.4 \text{ MeV} + 0.7 \text{ MeV})\ 1.6\ 10^{-13}\ 3600}{7} \text{ Gy/hr}$$

$\rightarrow$ 28 µGy/hr

D. E. Rate

$$\frac{(4.7\ 10^5)(5.4 \times 20 + 0.7 \times 1)\ 1.6\ 10^{-13}\ 3600}{60} \text{ Sv/hr}$$

$\rightarrow$ 490 µSv/hr

a)	28	µGy/hr

b)	490	µSv/hr

2. A population of 1 million people is accidentally exposed to radiation. Three hundred thousand people, Group A, receive on average 40 rem (0.4 Sv), while 700 000, Group B, on average receive 10 rem (0.1 Sv).

Calculate the number of deaths in each group that could reasonably be ascribed to radiation - induced cancer.

Gr A $3\times10^5 \times 40 \times 4\times10^{-4} = 4800$

Gr B $7\times10^5 \times 10 \times 4 \times10^{-4} = 2800$

7600

GrA	4800
GrB	2800

For the total 1,000,000, is the total number of deaths ("normal" plus radiation induced) significantly (in a statistical sense) different from the "normal" expected number. Give reason(s) for your opinion.

(This Q was badly worded. However I think most people read into it what was meant. Write to me if you feel you were badly treated)

250 000 of the million would be expected to die of cancer, with an error of $\sqrt{250\,000} = 500$

7600 is greater than 3 times the standard error, so 7600 is statistically significant

Yes or No	Y

Why do you come to this conclusion?

see text

3. When some identical colonies of cells are subject to x-rays the ln Survival versus Dose graph has a typical shoulder, with the shape being such that it seems as if 4 targets have to be hit for a cell to be "killed" and that the "sensitive volume" is 4.4 x 10^{-5} $(\mu m)^3$ ($v_s = \lambda/2$ if v_s is in $(\mu m)^3$ and λ in rad^{-1}; ln Survival is the natural logarithm of the number of survivng cells).

(a) Calculate the dose necessary to "kill" 50% of the cells of a colony.

$S_D = S_0 \, r \, e$, $\lambda = 8.8 \; 10^{-5} \; rad^{-1}$

S_0 here, $0.5 = 4 \, e^{-}$

$\lambda D = \ln 8 = 2.08$

$D = 23$ kilo rad

23 10^3 rad

(b) Starting with 100 cells, what dose will, on average, leave only 2 cells alive? With this dose, what is the probability that, starting with 100 cells, none survive?

$2 = 100 \, r \, e^{-\lambda D}$ with ~~same~~ values as above

$\rightarrow D = 60$ krad

$P(0,2) = \dfrac{2^0 e^{-2}}{0!} = 0.135$

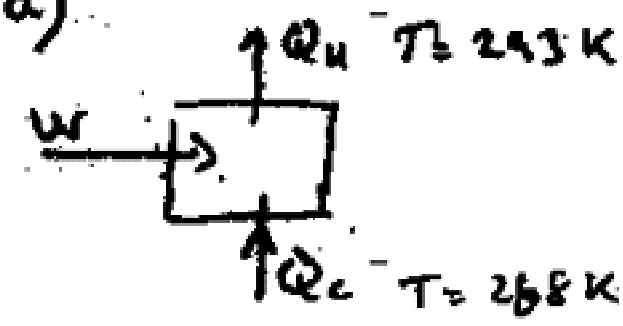
60 10^3 rad

P = 0.135

4. (a) In an ideal (Carnot) heat pump, heat is taken in at 268 K and pumped up to 293 K. If 1300 J are taken in per second, what is the necessary power (J/sec) of the pump driving this heat?

(b) If the system has in fact a Coefficient of Performance only 23% that of a corresponding Carnot pump, what has to be the power of the driving system for the same heat to be put out at 293K?

a)



For Carnot (reversible) cycle $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

So here $Q_H = \frac{1300}{268} 293 = 1421$ J/sec

Also $Q_c + W = Q_H$, so $W = Q_H - Q_c$ $\quad \begin{array}{r} 1421 \\ \underline{1300} \\ 121 \end{array}$

So $\underline{W = 121 \text{ J/s}}$

b) $\text{COP (HP) (Carnot)} = \frac{1}{\eta \text{ (Heat engine)}}$

$= \frac{1}{1 - T_c/T_H} = \frac{T_H}{T_H - T_c}$

with $T_H = 293$ and $T_c = 268$, $\text{COP (HP)(C)} = 11.72$

So $\underline{\text{real}}$ COP (HP) here is $0.23 \times 11.72 = 2.70$

ie $\frac{Q_{hot}}{W(\text{actual})} = 2.70$

So $W(\text{actual}) = \frac{Q_{hot}}{2.7} = \frac{1421}{2.7} = \underline{527}$

[Note that a) only for reversible cycle can one use $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

b) Q_c is $\underline{\text{not}}$ the same in a) & b) parts. Q_H $\underline{\text{is}}$ the same Σ (it says so!)]

a) 121	J/s
b) 527	J/s