PHY 238Y - LIFE SCIENCES II

MID-TERM TEST #2 - JANUARY 14, 2003

TIME: 50 MINUTES

All three questions (Q1, Q2 and Q3) have approximately equal mark value, but may not be of equal difficulty. Do all questions. Write in space provided

Calculators may be used.

Constants and Formulae

$P(x,m) = m^x e^{-m}/x!$
1 MeV = 1.6×10^{-13} J
0°C = 273 K
1 Gy = 1 J/kg
$Q(w_R)$ gamma rays = 1
1 litre = 10^{-3} m^3
$e = 1.6 \times 10^{-19}$ C

Density of water = 10^3 kg/m^3
$N_{AV} = 6.0 \times 10^{23}$
$\ell n\ 2 = 0.693$
Sv = Gy × Q (or w_R)
$Q(w_R)$ betas = 1
$Q(w_R)$ alphas = 20

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

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

Test Solutions

Q1

A tissue sample of 800 gm was found to have in it 2.4 micrograms of Pu-239. This isotope has a half-life of 2.4×10^4 years and emits an alpha particle of 5.1 MeV. Assuming that the Pu has been in that tissue mass for 15 years, and that there has been no biological transfer of Pu in or out of the tissue, what is

(a) the dose equivalent in Sv to the tissue?

(b) Make a rough estimate of the effective dose, that is the dose equivalent to the whole body which would cause as many cancers as the dose equivalent to the tissue.

a) Dose Equ. = Dose Rate × Time × WR

$$= \frac{\text{Dis/sec} \times \text{Energy/dis}}{m} \times T \times WR$$

$$= \frac{0.693}{2.4\ 10^4\ 3.1\ 10^7}\left(\frac{2.4\ 10^{-6}}{239}\ 6.0\ 10^{23}\right) \times \left[\frac{5.11 \times 1.6 \times 10^{-13}\ J}{0.8\ kg}\right]\ Gy/sec$$

$$\rightarrow \frac{0.693}{10^4\ 3.1\ 10^7}\ \frac{10^{-6}\ 6\ 10^{23}\ 5.1\ 1.6\ 10^{-13}}{239\ \ 0.8}$$

$$\times 20 \times 15 \times 3.1 \times 10^7\ Sv$$

$$\rightarrow 53\ Sv$$

b) Here we have 800 g of tissue — in whole body ~ 70000 g

Effective Dose Equ $\sim 53 \times \frac{800}{70000}$

$\sim 0.5\ Sv$

(a)	Sv
(b)	Sv

Q2

A colony of cells is irradiated by gamma rays. The dose-effect relationship is exponential, ie. $C_D = C_o e^{-\lambda D}$. λ is such that 2000 rads would reduce the original number of cells by a factor of 10.

(a) What dose would reduce the proportion of surviving cells to 0.1% of the original number?

(b) What is the D_{37} (ie. Dose for 37% survival)?

(c) Estimate the size of the sensitive volume of a cell.

$$C_D = C_o e^{-\lambda D}$$

Here, when D = 2000 r λ is such that

$$C_D = \frac{1}{10} C_o$$

$$1/10 = e^{-\lambda \cdot 2000}$$

This gives $\lambda = 1.15 \cdot 10^{-3}$ rads^{-1}

a) to get $C_D = 0.1\%\ C_o$

$$10^{-3} = e^{-1.15 \cdot 10^{-3} D}$$

$\Rightarrow D = 6000$ rads

b)

$$.37 = e^{-1.15 \cdot 10^{-4} D}$$

$$D = 870 \text{ rad.}$$

c)

$$V_s = \frac{\lambda}{2}$$ ← when V in (µm)^3, λ = rads^{-1}

$$= \frac{1.15 \cdot 10^{-3}}{2}$$

$$= 0.57 \cdot 10^{-3} \ (\mu m)^3$$

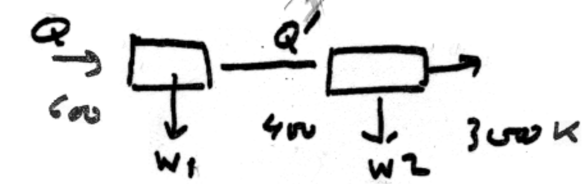
(a)	rads
(b)	rads
(c)	$(\mu m)^3$

Calculate the maximum theoretical efficiency of a Carnot heat engine working between 600 and 300 K.
Calculate also the corresponding overall efficiency under the conditions that heat is first supplied to an engine working between 600 K and 400 K. and the "waste" heat from this is supplied to an engine working between 400 K and 300 K.

a) $\eta_c \quad \frac{T_c}{T_H} = 1 - \frac{300}{600} = 0.5$

$\sim 50\%$

b)



$W_1 \quad Q\left(1 - \frac{T_L}{T_H}\right) = Q\left(1 \quad \frac{400}{600}\right) \quad 0.333\,Q$

$Q' \quad 0.666\,Q$

$W_2 = 0.666\,Q\left(1 \quad \frac{300}{400}\right)$

$= 0.666\,Q \quad 25$

$W \quad W_1 + W_2$

$0.333\,Q_H + 0.166\,Q$

$= 0.5\,Q$

$\eta \quad \frac{W}{Q} \quad 0\,5$

(a) $\eta = \frac{W}{Q} =$

(b) $\eta = \frac{W_1 + W_2}{Q} =$