UNIVERSITI SAINS MALAYSIA

Second Semester Examinations
1996/97 Academic Session

April 1997

ZCE 538/2 Radiobiology and Radiation Chemistry

Time: [2 hours]

Please make sure that this examination paper consists of THREE printed pages before you commence the examination.

Answer FOUR questions only.

1. (a) Describe what is meant by the following and sketch the relevant survival curves

   (i) single-hit model
   (ii) multi-hit model
   (iii) multi-target model

   (30/100)

   (b) (i) Define Linear Energy Transfer (LET) and discuss its influencing factors.
   (ii) Define Relative Biological Effectiveness (RBE) and discuss its influencing factors.
   (iii) Describe the relationship between Linear Energy Transfer (LET) and Relative Biological Effectiveness (RBE).

   (70/100)

2. (a) (i) Describe the method to produce cell synchrony.
   (ii) Discuss the effect of X-rays on synchronously dividing cell cultures.

   (50/100)

   (b) Two methods normally used to assess cell survival in vivo are (i) tumour dose-50 method and (ii) spleen nodule method. Describe both methods.

   (50/100)

3. (a) Define

   (i) plating efficiency
   (ii) surviving fraction

   (10/100)

...2/-

(b) In an unirradiated control, 200 cells were seeded. After seven days the cells were stained and it was found there are 140 colonies. 4000 similar cells were seeded in another dish and irradiated to 800 rads of X-rays and 64 colonies survived. Calculate

(i) plating efficiency
(ii) surviving fraction

(15/100)

(c) State the reasons as to why spheroid system is a better experimental tool.

(25/100)

(d) Describe the biological factors modifying the amount of damage in human body due to ionising radiation.

(50/100)

4. (a) Draw a graph of the life history of an irradiated tumour and describe in detail by taking different zones of the graph.

(50/100)

(b) Discuss

(i) bone marrow syndrome
(ii) central nervous system syndrome

(50/100)

5. (a) (i) Define

(1) Mitotic index
(2) Labelling index
(3) Growth fraction

(15/100)

(b) Describe in detail oxygen effect and reoxygenation.

(35/100)

(c) (i) A radiotheraphy centre practices a protocol of 30 dose at 200 rad, given as 5 treatment per week, is considered to represent normal tissue tolerance.

(1) What is the TDF value for this case?
(2) Due to a long waiting list, the above protocol has to be changed to 1 treatment per week at 320 rad. How many fractions are needed to achieve equivalent effect?

...3/-

(ii) To achieve complete treatment, the planned protocol is 26 dose at 220 rad, given as 4 treatment per week. However the staff concerned made a mistake by irradiating the patient at 250 rad and not 220 rad and this is realised after 7 fractions have been delivered.

(1) How many more doses must be given at 4 treatment per week?
(2) How many more doses must be given if the treatment is changed to 2 treatment per week?

(iii) After considering the double festive holidays, a radiotherapist planned the following treatment: 18 dose at 220 rad, given as 4 treatment per week followed by 6 dose at 320 rad, given as 3 treatment per week. However the machine broke down. It was repaired and after considering the treatment of other patients, the overall treatment was decided as 5 treatment per week. Calculate 3 regimes that he can choose to achieve equivalent effect.

(50/100)

- oooOooo -

TABLE 14–1. TDFs for One Treatment Day/Week

Dose/ fraction (rad)	Number of fractions																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4
60	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8
80	3	3	4	4	5	6	6	7	8	8	9	9	10	11	11	12	13
100	4	4	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18
110	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	21
120	5	6	7	8	9	11	12	13	14	15	16	18	19	20	21	22	24
130	5	7	8	9	11	12	13	15	16	17	19	20	21	23	24	25	27
140	6	7	9	10	12	13	15	16	18	19	21	22	24	25	27	28	30
150	7	8	10	12	13	15	17	18	20	22	23	25	27	28	30	32	33
160	7	9	11	13	15	17	18	20	22	24	26	28	29	31	33	35	37
170	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
180	9	11	13	15	18	20	22	24	26	29	31	33	35	37	40	42	44
190	10	12	14	17	19	22	24	26	29	31	33	36	38	41	43	45	48
200	10	13	16	18	21	23	26	28	31	34	36	39	41	44	47	49	52
210	11	14	17	20	22	25	28	31	33	36	39	42	45	47	50	53	56
220	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
230	13	16	19	22	26	29	32	35	38	42	45	48	51	54	58	61	64
240	14	17	21	24	27	31	34	38	41	44	48	51	55	58	62	65	68
250	15	18	22	26	29	33	36	40	44	47	51	55	58	62	66	69	73
260	15	19	23	27	31	35	39	43	46	50	54	58	62	66	70	74	77
270	16	21	25	29	33	37	41	45	49	53	57	62	66	70	74	78	82
280	17	22	26	30	35	39	43	48	52	56	61	65	69	74	78	82	87
290	18	23	27	32	37	41	46	50	55	60	64	69	73	78	82	87	92
300	19	24	29	34	39	43	48	53	58	63	68	72	77	82	87	92	96
320	21	27	32	37	43	48	53	59	64	69	75	80	85	91	96	101	107
340	23	29	35	41	47	53	58	64	70	76	82	88	94	99	105	111	117
360	26	32	38	45	51	57	64	70	77	83	89	96	102	109	115	121	128
380	28	35	42	49	56	62	69	76	83	90	97	104	111	118	125	132	139
400	30	38	45	53	60	68	75	83	90	98	105	113	120	128	135	143	150
420	32	40	49	57	65	73	81	89	97	105	113	121	129	138	146	154	
440	35	43	52	61	70	78	87	96	104	113	122	130	139	148	156		
460	37	47	56	65	74	84	93	102	112	121	130	140	149	158			
480	40	50	60	70	80	89	99	109	119	129	139	149	159				
500	42	53	63	74	85	95	106	116	127	138	148	159					
520	45	56	67	79	90	101	112	124	135	146	157						
540	48	60	71	83	95	107	119	131	143	155							
560	50	63	76	88	101	113	126	139	151								
580	53	66	80	93	106	120	133	146	160								
600	56	70	84	98	112	126	140	154									
700	71	89	107	124	142	160	178										
800	87	109	131	153	174												
900	105	131	157														
1000	123	154															

TABLE 14–2. TDFs for Two Treatment Days/Week

Dose/fraction (rad)	Number of fractions																					
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
20	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
40	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6
60	2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11
80	3	4	4	5	6	6	7	8	8	9	10	10	11	12	13	13	14	15	15	16	17	17
100	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
110	5	6	7	8	9	10	11	13	14	15	16	17	18	19	21	22	23	24	25	26	27	29
120	5	7	8	9	10	12	13	14	16	17	18	20	21	22	23	25	26	27	29	30	31	33
130	6	7	9	10	12	13	15	16	18	19	21	22	24	25	27	28	30	31	32	34	35	37
140	7	8	10	12	13	15	17	18	20	21	23	25	26	28	30	31	33	35	36	38	40	41
150	7	9	11	13	15	17	18	20	22	24	26	28	29	31	33	35	37	39	40	42	44	46
160	8	10	12	14	16	18	20	22	24	26	28	30	32	35	37	39	41	43	45	47	49	51
170	9	11	13	16	18	20	22	25	27	29	31	33	36	38	40	42	45	47	49	51	53	56
180	10	12	15	17	19	22	24	27	29	32	34	37	39	41	44	46	49	51	54	56	58	61
190	11	13	16	19	21	24	26	29	32	34	37	40	42	45	48	50	53	56	58	61	63	66
200	11	14	17	20	23	26	29	31	34	37	40	43	46	49	52	54	57	60	63	66	69	72
210	12	15	19	22	25	28	31	34	37	40	43	46	49	52	56	59	62	65	68	71	74	77
220	13	17	20	23	27	30	33	36	40	43	46	50	53	56	60	63	66	70	73	76	80	83
230	14	18	21	25	28	32	35	39	43	46	50	53	57	60	64	67	71	75	78	82	85	89
240	15	19	23	27	30	34	38	42	45	49	53	57	61	64	68	72	76	80	83	87	91	95
250	16	20	24	28	32	36	40	44	48	52	56	61	65	69	73	77	81	85	89	93	97	101
260	17	21	26	30	34	39	43	47	51	56	60	64	69	73	77	81	86	90	94	99	103	107
270	18	23	27	32	36	41	45	50	54	59	64	68	73	77	82	86	91	95	100	104	109	114
280	19	24	29	34	38	43	48	53	58	62	67	72	77	82	86	91	96	101	106	110	115	120
290	20	25	30	35	41	46	51	56	61	66	71	76	81	86	91	96	101	106	111	117	122	127
300	21	27	32	37	43	48	53	59	64	69	75	80	85	91	96	101	107	112	117	123	128	133
320	24	29	35	41	47	53	59	65	71	77	83	88	94	100	106	112	118	124	130	136	142	147
340	26	32	39	45	52	58	65	71	78	84	91	97	104	110	117	123	129	136	142	149	155	162
360	28	35	42	49	57	64	71	78	85	92	99	106	113	120	127	134	141	148	155	163		
380	31	38	46	54	61	69	77	84	92	100	108	115	123	131	138	146	154	161				
400	33	42	50	58	66	75	83	91	100	108	116	125	133	141	150	158						
420	36	45	54	63	72	81	90	99	107	116	125	134	143	152								
440	38	48	58	67	77	87	96	106	115	125	135	144	154									
460	41	52	62	72	82	93	103	113	124	134	144	155										
480	44	55	66	77	88	99	110	121	132	143	154											
500	47	59	70	82	94	105	117	129	141	152												
520	50	62	75	87	100	112	124	137	149	162												
540	53	66	79	92	105	119	132	145	158													
560	56	70	84	98	112	125	139	153														
580	59	74	88	103	118	132	147	162														
600	62	78	93	109	124	140	155															
700	79	98	118	138	157	177																
800	97	121	145	169																		
900	116	145	174																			
1000	136	170																				

(After Orton CG, Ellis F: Br J Radiol 46:529–537, 1973)

TABLE 14–3. TDFs for Three Treatment Days/Week

Dose/ fraction (rad)	Number of fractions																					
	4	5	6	8	10	12	14	15	16	18	20	22	24	25	26	28	30	32	34	35	36	40
20	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	4
40	1	1	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	9	9	9	10
60	2	2	3	4	5	6	7	7	8	9	10	10	11	12	12	13	14	15	16	17	17	19
80	3	4	4	6	7	9	10	11	12	13	15	16	18	19	19	21	22	24	25	26	27	30
100	4	5	6	8	10	13	15	16	17	19	21	23	25	26	27	29	31	33	36	37	38	42
110	5	6	7	10	12	15	17	18	19	22	24	27	29	30	32	34	36	39	41	42	44	48
120	6	7	8	11	14	17	19	21	22	25	28	30	33	35	36	39	42	44	47	48	50	55
130	6	8	9	13	16	19	22	24	25	28	31	34	38	39	41	44	47	50	53	55	56	63
140	7	9	11	14	18	21	25	26	28	32	35	39	42	44	46	49	53	56	60	61	63	70
150	8	10	12	16	20	23	27	29	31	35	39	43	47	49	51	55	59	62	66	68	70	78
160	9	11	13	17	22	26	30	32	35	39	43	47	52	54	56	60	65	69	73	75	78	86
170	9	12	14	19	24	28	33	36	38	43	47	52	57	59	62	66	71	76	80	83	85	95
180	10	13	16	21	26	31	36	39	41	47	52	57	62	65	67	72	78	83	88	90	93	103
190	11	14	17	22	28	34	39	42	45	51	56	62	67	70	73	79	84	90	96	98	101	112
200	12	15	18	24	30	36	43	46	49	55	61	67	73	76	79	85	91	97	103	106	109	122
210	13	16	20	26	33	39	46	49	52	59	66	72	79	82	85	92	98	105	111	115	118	131
220	14	18	21	28	35	42	49	53	56	63	70	77	84	88	92	99	106	113	120	123	127	141
230	15	19	23	30	38	45	53	57	60	68	75	83	90	94	98	106	113	121	128	132	136	151
240	16	20	24	32	40	48	56	60	64	72	80	89	97	101	105	113	121	129	137	141	145	161
250	17	21	26	34	43	51	60	64	69	77	86	94	103	107	111	120	129	137	146	150	154	
260	18	23	27	36	46	55	64	68	73	82	91	100	109	114	118	127	137	146	155			
270	19	24	29	39	48	58	68	72	77	87	96	106	116	121	125	135	145	154				
280	20	25	31	41	51	61	71	76	82	92	102	112	122	127	133	143	153					
290	22	27	32	43	54	65	75	81	86	97	108	118	129	135	140	151						
300	23	28	34	45	57	68	79	85	91	102	113	125	136	142	147	159						
320	25	31	38	50	63	75	88	94	100	113	125	138	150	157	163							
340	27	34	41	55	69	82	96	103	110	124	137	151										
360	30	38	45	60	75	90	105	113	120	135	150	165										
380	33	41	49	65	82	98	114	122	131	147	163											
400	35	44	53	71	88	106	124	132	141	159												
420	38	48	57	76	95	114	133	143	152													
440	41	51	61	82	102	123	143	153														
460	44	55	66	88	109	131	153															
480	47	58	70	93	117	140	164															
500	50	62	75	100	124	149	174															
520	53	66	79	106	132	159																
540	56	70	84	112	140	168																
560	59	74	89	118	148	178																
580	63	78	94	125	156																	
600	66	82	99	132	165																	
700	83	104	125	167																		
800	103	128	154																			
900	123	154																				
1000	145	181																				

(After Orton CG, Ellis F: Br J Radiol 46:529–537, 1973)

TABLE 14–4. TDFs for Four Treatment Days/Week

Dose/ fraction	Number of fractions																					
(rad)	4	5	6	8	10	12	14	15	16	18	20	22	24	25	26	28	30	32	34	35	36	40
20	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	4
40	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	11
60	2	3	3	4	5	6	7	8	8	9	10	11	12	13	13	14	15	16	17	18	18	20
80	3	4	5	6	8	9	11	12	13	14	16	17	19	20	20	22	23	25	27	27	28	31
100	4	6	7	9	11	13	15	17	18	20	22	24	26	28	29	31	33	35	37	39	40	44
110	5	6	8	10	13	15	18	19	20	23	26	28	31	32	33	36	38	41	43	45	46	51
120	6	7	9	12	15	18	20	22	23	26	29	32	35	36	38	41	44	47	50	51	53	58
130	7	8	10	13	16	20	23	25	26	30	33	36	40	41	43	46	49	53	56	58	59	66
140	7	9	11	15	18	22	26	28	30	33	37	41	44	46	48	52	55	59	63	65	67	74
150	8	10	12	16	21	25	29	31	33	37	41	45	49	51	53	58	62	66	70	72	74	82
160	9	11	14	18	23	27	32	34	36	41	45	50	54	57	59	64	68	73	77	79	82	91
170	10	12	15	20	25	30	35	37	40	45	50	55	60	62	65	70	75	80	85	87	90	100
180	11	14	16	22	27	33	38	41	44	49	54	60	65	68	71	76	82	87	93	95	98	109
190	12	15	18	24	30	35	41	44	47	53	59	65	71	74	77	83	89	95	101	103	106	118
200	13	16	19	26	32	38	45	48	51	58	64	70	77	80	83	90	96	102	109	112	115	128
210	14	17	21	28	34	41	48	52	55	62	69	76	83	86	90	97	103	110	117	121	124	138
220	15	19	22	30	37	44	52	56	59	67	74	82	89	93	96	104	111	119	126	130	133	148
230	16	20	24	32	40	48	56	60	63	71	79	87	95	99	103	111	119	127	135	139	143	159
240	17	21	25	34	42	51	59	64	68	76	85	93	102	106	110	119	127	136	144	148	152	
250	18	23	27	36	45	54	63	68	72	81	90	99	108	113	117	126	135	144	153	158		
260	19	24	29	38	48	57	67	72	77	86	96	105	115	120	125	134	144	153				
270	20	25	30	41	51	61	71	76	81	91	102	112	122	127	132	142	152					
280	21	27	32	43	54	64	75	81	86	97	107	118	129	134	140	150	161					
290	23	28	34	45	57	68	79	85	91	102	113	125	136	142	147	159						
300	24	30	36	48	60	72	84	90	96	107	119	131	143	149	155							
320	26	33	40	53	66	79	92	99	105	119	132	145	158	165								
340	29	36	43	58	72	87	101	109	116	130	145	159										
360	32	40	47	63	79	95	111	119	126	142	158											
380	34	43	52	69	86	103	120	129	137	155												
400	37	46	56	74	93	112	130	139	149	167												
420	40	50	60	80	100	120	140	150	160													
440	43	54	65	86	108	129	151															
460	46	58	69	92	115	138	161															
480	49	61	74	98	123	148	172															
500	52	65	79	105	131	157																
520	56	70	83	111	139	167																
540	59	74	88	118	147	177																
560	62	78	94	125	156																	
580	66	82	99	132	165																	
600	69	87	104	139	173																	
700	88	110	132	176																		
800	108	135	162																			
900	129	162																				
1000	152																					

(After Orton CG, Ellis F: Br J Radiol 46:529–537, 1973)

TABLE 14–5. TDFs for Five Treatment Days/Week

Dose/ fraction (rad)	Number of fractions																					
	4	5	6	8	10	12	14	15	16	18	20	22	24	25	26	28	30	32	34	35	36	40
20	0	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4
40	1	1	2	2	3	3	4	4	4	5	6	6	7	7	7	8	8	9	9	10	10	11
60	2	3	3	4	5	6	7	8	8	9	10	11	12	13	13	15	16	17	18	18	19	21
80	3	4	5	6	8	10	11	12	13	15	16	18	19	20	21	23	24	26	27	28	29	32
100	5	6	7	9	11	14	16	17	18	20	23	25	27	28	30	32	34	36	39	40	41	45
110	5	7	8	11	13	16	18	20	21	24	26	29	32	33	34	37	39	42	45	46	47	53
120	6	8	9	12	15	18	21	23	24	27	30	33	36	38	39	42	45	48	51	53	54	60
130	7	9	10	14	17	20	24	26	27	31	34	37	41	43	44	48	51	54	58	60	61	68
140	8	10	11	15	19	23	27	29	31	34	38	42	46	48	50	53	57	61	65	67	69	76
150	9	11	13	17	21	25	30	32	34	38	42	47	51	53	55	59	64	68	72	74	76	85
160	9	12	14	19	23	28	33	35	37	42	47	51	56	58	61	66	70	75	80	82	84	94
170	10	13	15	21	26	31	36	39	41	46	51	57	62	64	67	72	77	82	87	90	92	103
180	11	14	17	22	28	34	39	42	45	50	56	62	67	70	73	79	84	90	95	98	101	112
190	12	15	18	24	31	37	43	46	49	55	61	67	73	76	79	85	91	97	104	107	110	122
200	13	17	20	26	33	40	46	49	53	59	66	73	79	82	86	92	99	105	112	115	119	132
210	14	18	21	28	36	43	50	53	57	64	71	78	85	89	92	99	107	114	121	124	128	142
220	15	19	23	31	38	46	53	57	61	69	76	84	92	95	99	107	115	122	130	134	137	153
230	16	20	25	33	41	49	57	61	65	74	82	90	98	102	106	114	123	131	139	143	147	163
240	17	22	26	35	44	52	61	65	70	79	87	96	105	109	113	122	131	140	148	153	157	
250	19	23	28	37	46	56	65	70	74	84	93	102	112	116	121	130	139	149	158			
260	20	25	30	40	49	59	69	74	79	89	99	109	118	123	128	138	148	158				
270	21	26	31	42	52	63	73	78	84	94	105	115	126	131	136	146	157					
280	22	28	33	44	55	66	77	83	89	100	111	122	133	138	144	155						
290	23	29	35	47	58	70	82	88	93	105	117	128	140	146	152							
300	25	31	37	49	62	74	86	92	98	111	123	135	148	154								
320	27	34	41	54	68	82	95	102	109	122	136	149	163									
340	30	37	45	60	75	89	104	112	119	134	149	164										
360	33	41	49	65	81	98	114	122	130	147	163											
380	35	44	53	71	88	106	124	133	142	159												
400	38	48	57	77	96	115	134	144	153													
420	41	52	62	83	103	124	144	155														
440	44	55	67	89	111	133	155															
460	48	59	71	95	119	142	166															
480	51	63	76	101	127	152																
500	54	67	81	108	135	162																
520	57	72	86	115	143	172																
540	61	76	91	121	152																	
560	64	80	96	128	161																	
580	68	85	102	136	169																	
600	71	89	107	143	179																	
700	91	113	136	181																		
800	111	139	167																			
900	133	167																				
1000	157																					

(After Orton CG, Ellis F: Br J Radiol 46:529–537, 1973)