Carbon = Popn · E/person · C/E

E demand grows 1.5%/yr/person
C/E grows 1%/yr
Popn grows 1.5%/yr

$$C = P_0 e^{0.015t} \cdot E_0 e^{0.015t} \cdot C_0 e^{0.01t}$$
$$C = P_0 E_0 C_0 e^{0.04t}$$

a) how long until double current production

$$2 = e^{0.04t}$$
$$\ln 2 = 0.04t \rightarrow \frac{\ln 2}{0.04} = 17.32 \text{ yrs}$$

b) Fractional increase E/person?

$$\frac{Y}{Y_0} = e^{0.015(17.32)} \qquad \frac{Y}{Y_0} = 1.296$$

$$\frac{Y - Y_0}{Y_0} = 1.296 - 1 = .296 \quad \therefore \text{ 29.6\% increase in E/person}$$

c) Fractional increase total energy demand?

E/person · C/E

$$\frac{Y}{Y_0} = e^{0.025t} \qquad \frac{Y}{Y_0} = 1.54 \quad \therefore \text{ 54\% increase in total demand}$$

CIVE 1331 Problem 3.7

$$C\left(\frac{kg\,C}{yr}\right) = P \cdot \frac{E(kJ/yr)}{P} \cdot \frac{Carbon\,(kg\,C)}{E(kJ)}$$

$P_0 = 250 \cdot 10^6$ $E_0 = 320 \cdot 10^6$ $C_0 = 15 \cdot 10^{-6}$

$r = 0.6\%$ $r = 0.5\%$ $r = -0.3$

$t_0 = 1990$

a) $C(kg/yr)$ in 2020 $t - t_0 = 30\,yr$

$$C = P_0 e^{0.006(30)} E_0 e^{0.005(30)} C_0 e^{-0.003(30)}$$
$$= 1.52 \cdot 10^{12}\ kg\,C/yr$$

b) Carbon emmitted over 30 yr period

$$Q = \int_0^{30} C_0 e^{rt} = \frac{C_0}{r}(e^{rt} - 1)$$

$$= \frac{P_0 E_0 C_0}{0.008}\left(e^{0.008(30)} - 1\right) = 1.909 \cdot 10^{14} - 1.5 \cdot 10^{14} = 4 \cdot 10^{13}\ kg\,C$$

c) Total Energy Demand

$$P \cdot E = P_0 E_0 e^{0.008(30)} = 1.01 \cdot 10^{17}\ kJ/yr$$

d) Per Capita Carbon Emmision

$$E \cdot C = E_0 C_0 e^{0.002(30)} = 5.1 \cdot 10^3\ kg\,C/person$$

CIVE 3331 PROBLEM 3.12

Sewage drifting downstream decomposes as first-order delay at rate $K = 0.2$ /day

Half life = ? Fraction remaining after 5 days?

$$C = C_0 e^{-Kt} \qquad \frac{C}{C_0} = \frac{1}{2} = e^{-Kt}$$

$$\ln(1) - \ln(2) = -Kt$$

($\ln(1) \to 0$)

$$\frac{-\ln(2)}{-K} = t \qquad \text{half-life} \quad \frac{\ln(2)}{0.2} = \underline{\underline{3.46 \text{ days}}}$$

$$\frac{C}{C_0} = e^{-K(5)} = e^{-0.2(5)} = 0.36$$

$\therefore$ 36% remains after 5 days.

CIVE 3331 PROBLEM 3.15

Stock pond with 100 fish, popn. follows logistic curve up to stable population of 2000 fish.

a) Population size for maximum sustained fish yield?

$$N^* = \frac{K}{2} = 1000 \text{ fish.}$$

$$\text{Yield} = rN\left(1 - \frac{N}{K}\right)$$

Need r (in problem we are told population doubles every year for first couple of years)

Estimate rate using exponential growth

$N_0 = 100$

$N_1 = 200$ $\quad 2 = e^{r1}$ $\quad \ln(2) = r = 0.69/\text{yr.}$

$N_2 = 400$ $\quad 4 = e^{r2}$ $\quad \frac{\ln 4}{2} = r = 0.69/\text{yr.}$

$$Y = (0.69)(1000)\left(1 - \frac{1000}{2000}\right) = 346 \text{ fish/yr harvest}$$

b) Y at N = 1500 fish?

$$Y = (0.69)(1500)\left(1 - \frac{1500}{2000}\right) = 258 \text{ fish/yr harvest}$$

CIVE 3331 PROBLEM 3.17

K = 10,000 fish, Harvest 2000/yr. Popn 4000 steady. If you want to maximize the sustained yield what popn size & yield should be used.

$$Y = r(4000)\left(1 - \frac{4000}{10000}\right) = 2000$$

Solve for r

$$r = \frac{2000}{2400} = 0.83$$

$$Y_{max} = 0.83(5000)\left(1 - \frac{5000}{10000}\right) = 2075$$

∴ Harvest 2075 fish/yr; Popn = 5000 fish.

CIVE3331 PROBLEM 3.20

Population age structure

1) 0-24 = $3 \cdot 10^6$
2) 25-49 = $2 \cdot 10^6$
3) 50-74 = $1 \cdot 10^6$

All births between groups 1 & 2

All deaths at end of 3.

Current have replacement level fertility project age structure in 25 years, 50 years, 75 years.

Replacement fertility = 1 child/person
2 child/woman

t_0

	♂	♀	
1	1.5E6	1.5E6	3
2	1E6	1E6	2
3	0.5E6	0.5E6	1

$6 \cdot 10^6$ people

t_{25}

1.5E6	1.5E6	3
1.5E6	1.5E6	3
1E6	1E6	2

$8 \cdot 10^6$ people

t_{50}

1.5E6	1.5E6	3
1.5E6	1.5E6	3
1.5E6	1.5E6	3

$9 \cdot 10^6$ people

t_{75}

1.5E6	1.5E6
1.5E6	1.5E6
1.5E6	1.5E6

$9 \cdot 10^6$ people

UVE3331 PROBLEM 3.23/3.24

Age & Survival Data for China in 1980.
Suppose TFR = 1.0. Estimate population in 10 years, 20 years, 50 years.

Age	P(million)	L_{x+10}/L	b_x
0-9	234	0.957	0
10-19	224	0.987	0.25
20-29	182	0.980	0.25
30-39	124	0.964	0
40-49	95	0.924	0
50-59	69	0.826	0
60-69	42	0.633	0
70-79	24	0.316	0
80-89	6	0	0
Total	1001	0	

See attached spreadsheet

	A	B	C	D	E	F	G	H	I	J
1	Population Projection - Age Structure and Mortality for China									
2					Year-0	Year-10	Year-20	Year-30	Year-40	Year-50
3	Age	P(millions)	L+/L	birth/P	1980	1990	2000	2010	2020	2030
4	0-9	235	0.957	0	235	101.5	111.5	79.8	50.6	45.4
5	10-19	224	0.987	0.25	224	224.9	97.1	106.7	76.3	48.5
6	20-29	182	0.98	0.25	182	221.1	222.0	95.9	105.3	75.4
7	30-39	124	0.964	0	124	178.4	216.7	217.5	94.0	103.2
8	40-49	95	0.924	0	95	119.5	171.9	208.9	209.7	90.6
9	50-59	69	0.826	0	69	87.8	110.5	158.9	193.0	193.8
10	60-69	42	0.633	0	42	57.0	72.5	91.2	131.2	159.4
11	70-79	24	0.316	0	24	26.6	36.1	45.9	57.8	83.1
12	80-89	6	0	0	6	7.6	8.4	11.4	14.5	18.2
13				Total	1001	1024.3	1046.6	1016.2	932.4	817.5