3 Chemistry

Content in blue refers to the *NCEES Handbook*.

PRACTICE PROBLEMS

1. Chlorine gas is used for the disinfection of a municipal drinking water supply. The chlorine gas reacts with the water to form hypochlorous acid (HOCl) at a concentration of 4 mg/L. The water temperature is 15°C. The pK_a for hypochlorous acid at 15°C is 7.63. The hydrogen ion concentration in the water from the dissociation of the hypochlorous acid is most nearly

(A) 2.3×10^{-8} M

(B) 1.3×10^{-6} M

(C) 7.5×10^{-5} M

(D) 7.6×10^{-5} M

2. Chlorine gas reacts with water to form hypochlorous acid (HOCl). Which of the following statements is true regarding the dissociation of HOCl in water at equilibrium?

(A) $[HOCl] = [OCl^-] + [H^+]$

(B) $[HOCl] = [OCl^-]$

(C) $[HOCl] = [H^+]$

(D) $[OCl^-] = [H^+]$

3. Chlorine gas is used for the disinfection of a municipal drinking water supply. The chlorine gas reacts with the water to form hypochlorous acid (HOCl) at a concentration of 4 mg/L. The water temperature is 15°C. If the hypochlorous acid concentration is 1.3×10^{-6} M, the percent ionization of the hypochlorous acid in the water is most nearly

(A) 1.3%

(B) 13%

(C) 74%

(D) 100%

4. Calcium ions (Ca^{+2}) and carbonate ions $\left(CO_3^{-2}\right)$ are present in a water sample at concentrations of 25 mg/L and 15 mg/L, respectively. The water temperature is 16°C. The solubility product constant, K_{SP}, for $CaCO_3$ is 5.0×10^{-9} at $T_1 = 25°C$ (298K). Solubility product constants at different absolute temperatures, T_1 and T_2, are related by

$$\ln \frac{K_{SP,T2}}{K_{SP,T1}} = \frac{-\Delta H°(T_1 - T_2)}{RT_1T_2}$$

R is the ideal gas constant. The standard enthalpies, $\Delta H°$, for the reactants and product are

$$\Delta H° \; Ca^{2+} = -543.0 \text{ kJ/mol}$$
$$\Delta H° \; CO_3^{2-} = -676.3 \text{ kJ/mol}$$
$$\Delta H° \; CaCO_3 = -1207.0 \text{ kJ/mol}$$

The solubility product for $CaCO_3$ at 16°C is most nearly

(A) 5.8×10^{-9}

(B) 1.6×10^{-7}

(C) 2.5×10^{-4}

(D) 6.3×10^{-4}

5. What effect do temperature and salinity have on the dissolved oxygen (DO) concentration in water?

(A) Increasing temperature raises DO; increasing salinity raises DO.

(B) Increasing temperature lowers DO; increasing salinity raises DO.

(C) Increasing temperature raises DO; increasing salinity lowers DO.

(D) Increasing temperature lowers DO; increasing salinity lowers DO.

6. Bench scale aeration tests are performed on a sample of water that is being evaluated for air stripping to remove VOCs. The target VOC is present in the water sample before aeration at 990 μg/L. The tests produce the following data.

7 Hydrology and Hydrogeology

Content in blue refers to the *NCEES Handbook*.

PRACTICE PROBLEMS

1. Rainfall records for four precipitation stations are summarized in the following table.

station	normal annual precipitation (cm)	annual precipitation for year indicated (cm)		
		year 1	year 2	year 3
A	27	26	24	31
B	31	29	27	30
C	26	33		29
D	29	27	26	28

Stations A, B, C, and D are located in close proximity to each other. What is the value for the missing record at Station C for year 2?

(A) 23 cm

(B) 26 cm

(C) 29 cm

(D) 31 cm

2. A watershed occupies a 30 ha site. 18 ha of the site have been cleared and are used for pasture land; 1 ha is occupied by farm buildings, a house, and paved surfaces; the remaining 11 ha are woodland. The average land slope is 2.1%. Because the site is upland from a residential development, the rainfall runoff from the site is collected in a catchment that discharges directly to a culvert. The overland flow distance to the catchment is 212 m. The weighted average runoff coefficient for the watershed is most nearly

(A) 0.07

(B) 0.18

(C) 0.34

(D) 0.62

3. 20 years of 24-hour annual peak discharge values are summarized as shown in the table.

year	annual peak discharge (m^3/s)
1995	112
1996	94
1997	54
1998	49
1999	42
2000	51
2001	128
2002	103
2003	88
2004	96
2005	65
2006	79
2007	83
2008	71
2009	57
2010	89
2011	62
2012	53
2013	64
2014	92

The peak discharge expected for the average 2 yr, 24 h storm is most nearly

(A) 42 m^3/s

(B) 46 m^3/s

(C) 50 m^3/s

(D) 75 m^3/s

4. An urban parkland with a uniform slope of 0.0081 ft/ft experiences sheet flow runoff over a distance of 112 ft. The runoff coefficient of the urban parkland is 0.20. The rainfall intensity is 2.1 in/hr. The inlet time is most nearly

(A) 6 min

(B) 8 min

(C) 40 min

(D) 70 min

Water

13. Stormwater runoff from a fully developed urban area is collected for treatment prior to discharge into an estuary. The stormwater enters a basin used for treatment to remove suspended solids and for retention. The maximum runoff flow into the basin is 10 cfs for a 30 min period and the maximum allowed discharge from the basin is 1 cfs. The settling time in the basin is most nearly

(A) 0.50 hr

(B) 2.2 hr

(C) 4.5 hr

(D) 5.0 hr

2. The average runoff coefficient for each land use type is shown in the table.

land use	area (ha)	runoff coefficient range	average runoff coefficient
pasture	18	0.05–0.45	0.25
developed	1	0.5–0.95	0.73
woodland	11	0.05–0.25	0.15

The weighted average runoff coefficient for the watershed is

$$\frac{(0.25)(18\text{ ha})+(0.73)(1\text{ ha})+(0.15)(11\text{ ha})}{30\text{ ha}}=0.23$$

The answer is (B).

SOLUTIONS

1. Calculate the differences in normal annual precipitation among the four stations.

$$\frac{26\text{ cm}-27\text{ cm}}{26\text{ cm}}\times 100\% = 3.8\%$$

$$\frac{26\text{ cm}-31\text{ cm}}{26\text{ cm}}\times 100\% = 19\%$$

$$\frac{26\text{ cm}-29\text{ cm}}{26\text{ cm}}\times 100\% = 12\%$$

Because the normal annual precipitation among stations varies by more than 10%, use the normal ratio method.

$$\begin{aligned} P_x &= \frac{1}{3}\left[\left(\frac{N_x}{N_A}\right)P_A+\left(\frac{N_x}{N_B}\right)P_B+\left(\frac{N_x}{N_D}\right)P_D\right] \\ &= \frac{1}{3}\left[\begin{array}{l}\left(\frac{26\text{ cm}}{27\text{ cm}}\right)(24\text{ cm})+\left(\frac{26\text{ cm}}{31\text{ cm}}\right)(27\text{ cm}) \\ \quad +\left(\frac{26\text{ cm}}{29\text{ cm}}\right)(26\text{ cm})\end{array}\right] \\ &= 23\text{ cm}\end{aligned}$$

The answer is (A).

2. The typical runoff coefficient for each land use type is shown in the table.

land use	area (ha)	typical runoff coefficient
pasture	18	0.13
developed	1	0.75
woodland	11	0.20
	30	

The weighted average runoff coefficient for the watershed is

$$\frac{(0.13)(18\text{ ha})+(0.75)(1\text{ ha})+(0.20)(11\text{ ha})}{30\text{ ha}}=0.18$$

The answer is (B).

3. Carbonate hardness is the lesser of the concentration of total alkalinity and total hardness in mg/L as $CaCO_3$. All alkalinity for the water sample is from HCO_3^-.

The total alkalinity is

$$\left(6.25\ \frac{\text{meq}}{\text{L}}\right)\left(\frac{50\ \text{mg as } CaCO_3}{1\ \text{meq}}\right) = 312.5\ \text{mg/L as } CaCO_3 \quad (310\ \text{mg/L as } CaCO_3)$$

The total hardness is

$$\begin{aligned} &Ca^{+2}\ \frac{\text{mg}}{\text{L}}\ \text{as } CaCO_3 + Mg^{+2}\ \frac{\text{mg}}{\text{L}}\ \text{as } CaCO_3 \\ &= \left(7.90\ \frac{\text{meq}}{\text{L}} + 3.92\ \frac{\text{meq}}{\text{L}}\right)\left(\frac{50\ \text{mg as } CaCO_3}{1\ \text{meq}}\right) \\ &= 591\ \text{mg/L as } CaCO_3 \quad (590\ \text{mg/L as } CaCO_3) \end{aligned}$$

310 mg/L as $CaCO_3$ is less than 590 mg/L as $CaCO_3$. Therefore, the carbonate hardness is equal to the total alkalinity.

The answer is (B).

4. Carbonate hardness is the lesser of the concentration of total alkalinity and total hardness in mg/L as $CaCO_3$.

The total alkalinity is

$$\left(6.25\ \frac{\text{meq}}{\text{L}}\right)\left(\frac{50\ \text{mg as } CaCO_3}{1\ \text{meq}}\right) = 312.5\ \text{mg/L as } CaCO_3 \quad (310\ \text{mg/L as } CaCO_3)$$

The total hardness is

$$\begin{aligned} &Ca^{+2}\ \frac{\text{mg}}{\text{L}}\ \text{as } CaCO_3 + Mg^{+2}\ \frac{\text{mg}}{\text{L}}\ \text{as } CaCO_3 \\ &= \left(7.90\ \frac{\text{meq}}{\text{L}} + 3.92\ \frac{\text{meq}}{\text{L}}\right)\left(\frac{50\ \text{mg as } CaCO_3}{1\ \text{meq}}\right) \\ &= 591\ \text{mg/L as } CaCO_3 \quad (590\ \text{mg/L as } CaCO_3) \end{aligned}$$

The non-carbonate hardness is

$$\begin{aligned} &\text{non-carbonate hardness} \\ &\quad = \text{total hardness} - \text{carbonate hardness} \\ &\quad = 590\ \frac{\text{mg}}{\text{L}}\ \text{as } CaCO_3 - 310\ \frac{\text{mg}}{\text{L}}\ \text{as } CaCO_3 \\ &\quad = 280\ \text{mg/L as } CaCO_3 \end{aligned}$$

The answer is (B).

5. The annual flow rate is

$$\left(18\,000\ \frac{\text{m}^3}{\text{d}}\right)\left(365\ \frac{\text{d}}{\text{yr}}\right) = 6.57 \times 10^6\ \text{m}^3/\text{yr}$$

ion	concentration (mg/L)	mole weight (mg/mmol)	concentration (mmol/L)
Ca^{+2}	347	40	8.675
Mg^{+2}	129	24	5.375
HCO_3^-	1256	61	20.590

Find the molecular weight of $CaCO_3$. [Periodic Table of Elements]

$$40\ \frac{\text{mg}}{\text{mmol}} + 12\ \frac{\text{mg}}{\text{mmol}} + (3)\left(16\ \frac{\text{mg}}{\text{mmol}}\right) = 100\ \text{mg/mmol}$$

The molecular weight of $Mg(OH)_2$ is

$$24\ \frac{\text{mg}}{\text{mmol}} + (2)\left(16\ \frac{\text{mg}}{\text{mmol}} + 1\ \frac{\text{mg}}{\text{mmol}}\right) = 58\ \text{mg/mmol}$$

From Eq. I, 8.675 mmol/L Ca^{+2} reacts with (2)(8.675 mmol/L) HCO_3^- and 8.675 mmol/L CaO to produce (2)(8.675 mmol/L) $CaCO_3$. Of the 20.59 mmol/L HCO_3^-, Eq. I consumes (2)(8.675 mmol/L) leaving 3.24 mmol/L for reaction in Eq. II.

From Eq. II, the remaining 3.24 mmol/L HCO_3^- reacts with (½)(3.24 mmol/L) Mg^{+2} and 3.24 mmol/L CaO to produce 3.24 mmol/L $CaCO_3$ and (½)(3.24 mmol/L) $Mg(OH)_2$. Of the 5.375 mmol/L Mg^{+2}, Eq. II consumes (½)(3.24 mmol/L) leaving 3.755 mmol/L for reaction in Eq. III.

From Eq. III, the remaining 3.755 mmol/L Mg^{+2} reacts with 3.755 mmol/L CaO to produce 3.755 mmol/L Ca^{+2} and 3.755 mmol/L $Mg(OH)_2$.

The total amount of $CaCO_3$ produced is

$$\frac{\left((2)\left(8.675\ \frac{\text{mmol}}{\text{L}}\right) + 3.24\ \frac{\text{mmol}}{\text{L}} + 3.755\ \frac{\text{mmol}}{\text{L}}\right) \times \left(100\ \frac{\text{mg}}{\text{mmol}}\right)\left(6.57 \times 10^6\ \frac{\text{m}^3}{\text{yr}}\right)}{\left(\frac{1\ \text{m}^3}{1000\ \text{L}}\right)\left(10^6\ \frac{\text{mg}}{\text{kg}}\right)} = 1.6 \times 10^7\ \text{kg/yr} \quad \text{[dry]}$$

46 Sampling and Measurement Methods

Content in blue refers to the *NCEES Handbook*.

PRACTICE PROBLEMS

1. The characteristics of an organic chemical in solution with water are shown.

influent concentration = 1.57 mg/L
required effluent concentration = 0.05 mg/L
vapor pressure = 0.11 atm at 20°C
solubility in water = 1250 mg/L at 20°C
molecular weight = 87 g/mol
temperature = 20°C

The value of Henry's constant in unitless form is most nearly

(A) 8.8×10^{-5}

(B) 7.7×10^{-3}

(C) 0.32

(D) 93

2. Properties of different organic chemicals are given in the following table.

	solubility in water (mg/L)	specific gravity
chemical 1	1170	0.92
chemical 2	infinite	0.97
chemical 3	1740	1.13
chemical 4	59	0.78

Which chemical will exist as light nonaqueous phase liquid (LNAPL) if present in groundwater at a concentration of 1080 mg/L?

(A) chemical 1

(B) chemical 2

(C) chemical 3

(D) chemical 4

3. Groundwater resources in the United States are classified as Class I, II, or III waters based on water quality indicators. What classifies a water source as Class III?

(A) current or potential source of drinking water and having other beneficial uses

(B) highest potential beneficial use is drinking water and located in a potentially vulnerable setting

(C) not a potential drinking water source and having limited other beneficial uses

(D) not a potential drinking water source but having other potentially beneficial uses

4. A chemical is at equilibrium in a soil-groundwater system. The soil is an organic loam and the chemical is present in the soil at a concentration of 783 mg/kg. The concentration of the chemical in the groundwater is 1231 mg/L. The value of the organic carbon partition coefficient is most nearly

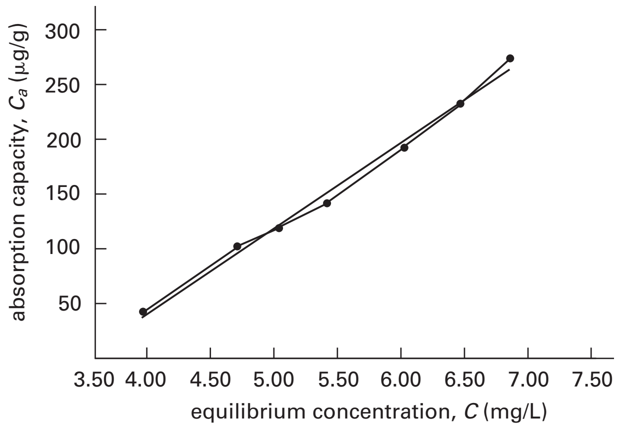
(A) 0.32

(B) 0.64

(C) 0.96

(D) 1.6

5. The results of a soil adsorption isotherm test using groundwater contaminated with an organic chemical are shown in the illustration.



Site Assessment & Remediation

48 Risk Assessment

Content in blue refers to the *NCEES Handbook*.

PRACTICE PROBLEMS

1. Which of the following is NOT among the four steps that traditionally define the risk assessment process?

(A) dose-response assessment

(B) exposure assessment

(C) health effects assessment

(D) risk characterization

2. In risk assessment, to what does the term "hazard" refer?

(A) identification of a risk

(B) quantification of a risk

(C) existence of a toxin

(D) occurrence of exposure

3. What are the four basic elements of risk assessment?

(A) hazard identification, population characterization, chemical assessment, risk characterization

(B) hazard identification, dose-response assessment, exposure assessment, risk characterization

(C) dose-response assessment, chemical assessment, population characterization, risk characterization

(D) dose-response assessment, chemical assessment, exposure assessment, risk characterization

4. Subchronic animal studies are performed to evaluate the noncarcinogenic toxic effects of a chemical compound. The no observed adverse effect level (NOAEL) of the chemical compound is 287 mg/kg·d. The uncertainty factors are shown in the table.

description	factor
uncertainty factor for population effects	10
uncertainty factor for extrapolating animal data to humans	10
uncertainty factor for using NOAEL from subchronic instead of chronic studies	10
uncertainty factor for using LOAEL instead of NOAEL	10
safety factor for other issues based on professional judgment	5

The administered oral reference dose is most nearly

(A) 0.0057 mg/kg·d

(B) 0.029 mg/kg·d

(C) 0.057 mg/kg·d

(D) 0.11 mg/kg·d

5. Subchronic animal studies are performed to evaluate the noncarcinogenic toxic effects of a chemical compound. The chemical compound is administered to the animals by ingestion of food with a 20% absorption efficiency. The administered oral reference dose is 0.0087 mg/kg·d. The absorbed oral reference dose for the chemical compound by ingestion of food is most nearly

(A) 0.0017 mg/kg·d

(B) 0.0088 mg/kg·d

(C) 0.034 mg/kg·d

(D) 0.44 mg/kg·d

6. Subchronic animal studies are performed to evaluate the noncarcinogenic toxic effects of a chemical compound. The chemical compound is administered to the animals by ingestion of food with a 20% absorption efficiency. If administered by ingestion of drinking water, the absorption efficiency is estimated to increase to 90%. The absorbed oral reference dose is 0.0013 mg/kg·d. The equivalent administered oral reference dose

Calculate the probability.

$$
\begin{aligned}
P(Z \geq 1.08) &= 1 - F(1.08) \\
&= 1 - 0.8597 \\
&= 0.1403 \quad (14\%)
\end{aligned}
$$

The answer is (A).

10. R_A, R_B, and R_C are the reliability of components A, B, and C, respectively. The overall system reliability is

$$
\begin{aligned}
R_\text{system} &= R_\text{A} R_\text{B} R_\text{C} \\
&= (0.93)(0.97)(0.96) \\
&= 0.87
\end{aligned}
$$

The answer is (A).

11. R_A, R_B, and R_C are the reliability of components A, B, and C, respectively. The reliability of stage B is

$$
\begin{aligned}
R_\text{B} &= 1 - (1 - R_\text{B1}) - (1 - R_\text{B2}) \\
&= 1 - (1 - 0.83) - (1 - 0.81) \\
&= 0.97
\end{aligned}
$$

Find the overall system reliability.

$$
\begin{aligned}
R_\text{system} &= R_\text{A} R_\text{B} R_\text{C} \\
&= (0.98)(0.97)(0.98) \\
&= 0.93
\end{aligned}
$$

The answer is (D).

12. Use the equation for reliability, and rearrange to solve for the failure rate.

$$
\begin{aligned}
R_t &= \text{reliability at time } t \\
\lambda &= \text{failure rate}
\end{aligned}
$$

$$
\begin{aligned}
R_t &= e^{-\lambda t} \\
\lambda &= -\frac{\ln R_t}{t}
\end{aligned}
$$

For component A,

$$
\lambda = -\frac{\ln 0.95}{1000 \text{ h}} = 5.13 \times 10^{-5} \text{ failures/h}
$$

The reliability of component B is

$$
\begin{aligned}
R_\text{B} &= 1 - (1 - R_\text{B1}) - (1 - R_\text{B2}) - (1 - R_\text{B3}) \\
&= 1 - (1 - 0.78) - (1 - 0.80) - (1 - 0.79) \\
&= 0.99
\end{aligned}
$$

The failure rate for component B is

$$
\lambda = -\frac{\ln 0.99}{1000 \text{ h}} = 1.00 \times 10^{-5} \text{ failures/h}
$$

The system failure rate is

$$
\begin{aligned}
&5.13 \times 10^{-5} \ \frac{\text{failures}}{\text{h}} + 1.00 \times 10^{-5} \ \frac{\text{failures}}{\text{h}} \\
&\quad = 6.13 \times 10^{-5} \text{ failures/h} \quad (6.1 \times 10^{-5} \text{ failures/h})
\end{aligned}
$$

The answer is (A).

13. The probability scale plots at the standardized mean and one standard deviation above and below the mean.

From a unit normal distribution table, for $x = 1.0$, the value of the unit standard deviation above and below the mean is 0.6827. Therefore, one unit standard deviation either above or below the mean is 0.341.

The x-values for coordinates are

$$
\begin{aligned}
&0.5 \\
&0.5 + 0.341 = 0.841 \\
&0.5 - 0.341 = 0.159
\end{aligned}
$$

The rainfall scale plots at the mean for the data and one standard deviation for the data above and below the mean.

The y-values for coordinates are

$$
\begin{aligned}
&48 \\
&48 + 11.2 = 59.2 \\
&48 - 11.2 = 36.8
\end{aligned}
$$

The plotting coordinates are

$$
\begin{aligned}
&(0.5, 48) \\
&(0.841, 59.2) \\
&(0.159, 36.8)
\end{aligned}
$$

The answer is (B).

14. Calculate the variance of X, $V[X]$.

$$
\begin{aligned}
\mu &= \text{expected value of } X, E[X] \\
\sigma^2 &= \text{variance}
\end{aligned}
$$

61 Economics: Cash Flow, Interest, Decision-Making

Content in blue refers to the *NCEES Handbook*.

PRACTICE PROBLEMS

1. Bench studies have determined that aluminum sulfate (alum) promotes acceptable floc formation at a dose of 23 mg/L when applied to a surface water source. The water demand is 19 000 m^3/d. Alum is available from one supplier at 17% purity for $234/1000 kg or from a second supplier at 26% purity at $319/1000 kg. The project has a 10-year life. The interest rate is 4% from the first supplier and 5% from the second supplier. By comparing costs at the end of the project life, the price difference between the two suppliers is most nearly

(A) less than $30,000

(B) between $30,000 and $50,000

(C) between $50,000 and $70,000

(D) more than $70,000

2. A precious metals mine produces 20 000 m^3/d of wastewater containing free cyanide (CN^-) at 1400 mg/L. The wastewater meets discharge criteria if the free cyanide is oxidized to cyanate (CNO^-). The daily mass of chlorine required to treat the wastewater is 77 000 kg. Chlorine gas at a purity of 99.8% is available at $584 for 1000 kg. The price includes transportation to the site. The oxidation treatment process will operate continuously 24 h per day and 365 d per year. The project uses a fixed amount of chlorine each year. This year, the cost of the chlorine used is $16,446,212. The cost of chlorine is expected to increase each year by an amount equal to 4% of this year's cost. For a net financing cost of 6%, the total present worth of the chlorine cost over 12 years is most nearly

(A) $27,000,000

(B) $138,000,000

(C) $164,000,000

(D) $201,000,000

3. A precious metals mine produces 20 000 m^3/d of wastewater containing free cyanide (CN^-) at 1400 mg/L. The wastewater can meet discharge criteria if the free cyanide is oxidized to cyanate (CNO^-). The daily mass of ozone required to treat the water is 52 000 kg. The ozone generator used for treatment produces 3.5% O_3, with a power requirement of 14 kW·h/kg of ozone produced. Electrical power costs $0.042/kW·h. The oxidation treatment process will operate continuously 24 h per day and 365 d per year. For a net annual financing cost of 6%, the uniform annual cost for ozone over the first three years of the project is most nearly

(A) $7,700,000/yr

(B) $11,000,000/yr

(C) $17,000,000/yr

(D) $22,000,000/yr

4. To offset energy costs, natural gas use at a wastewater treatment plant will be augmented with methane gas recovered from the plant's anaerobic digesters. A mixture of 70% methane and 30% natural gas will be used. The plant currently pays $0.020/$ft^3$ for natural gas. The expected operating and amortized capital cost of digester gas to scrub the methane before blending is $0.0080/$ft^3$, and the blending will continue full time 365 days per year. Total gas production by the digesters is expected to peak at 38,000 ft^3/day, 65% of which will be methane. Most nearly, what will be the approximate annual present worth savings over a 10–year period at 4% annual inflation rate over the current natural gas costs if all the available methane gas, when blended with the natural gas, precisely meets the needs of the plant?

(A) $560,000

(B) $830,000

(C) $890,000

(D) $1,300,000

Assoc. Eng. Principles

62 Economics: Capitalization, Depreciation, Accounting

Content in blue refers to the *NCEES Handbook*.

PRACTICE PROBLEMS

1. Electrical use by a pump operating at 100% efficiency is 2.6×10^4 N·m/s. The cost of electricity is \$0.10/kW·h. For a motor efficiency of 87% and a net interest rate of 8%, the amount of money that should be reserved today to cover the electrical costs over the next five years is most nearly

(A) \$91,000

(B) \$105,000

(C) \$110,000

(D) \$135,000

2. A city purchased refuse collection trucks for \$1.5M. The purchase is financed over an eight-year term at an annual interest rate of 4%. The trucks will have \$130,000 salvage value at the end of the eight-year term. The annual maintenance costs are shown in the following table.

year	cost
1	\$45,000
2	\$48,000
3	\$51,000
4	\$54,000
5	\$57,000
6	\$60,000
7	\$63,000
8	\$66,000

How much money should the city borrow to finance the project over the eight-year term?

(A) \$1,750,000

(B) \$1,800,000

(C) \$1,850,000

(D) \$1,950,000

3. A developer is offered property at a price of \$560,000. She can finance the property with a 10% down payment and equal monthly payments of \$12,700 over a five-year period. The effective interest rate of the transaction is most nearly

(A) 1.08%

(B) 1.33%

(C) 1.47%

(D) 2.65%

4. Earth moving equipment is purchased for \$280,000 with no money for the down payment. The buyer pays for the equipment in 60 equal monthly payments at an annual interest rate of 6% compounded continuously. The monthly payment is most nearly

(A) \$4,810

(B) \$4,950

(C) \$5,440

(D) \$8,060

5. A maintenance facility is constructed at a cost of \$7,800,000 with financing at 4% interest over a five-year term. The facility has the following anticipated annual operating costs also financed at a 4% annual interest rate.

year	cost
1	\$430,000
2	\$440,000
3	\$480,000
4	\$510,000
5	\$560,000

The equivalent uniform annual cost of the facility is most nearly

(A) \$663,000

(B) \$701,000

(C) \$894,000

(D) \$1,185,000

6. Compare two alternatives. The first alternative has a capital cost of $1,200,000 and an annual operation and maintenance cost of $140,000. The second alternative has a capital cost of $1,6000,000 and an annual operation and maintenance cost of $95,000. After the first year, the operation and maintenance cost will increase annually by 5%. For a 15-year project term and an annual interest rate of 4%, which alternative results in the least present worth cost?

(A) alternative 1 has the least present worth by $40,000

(B) alternative 1 has the least present worth by $63,000

(C) alternative 2 has the least present worth by $232,000

(D) alternative 2 has the least present worth by $275,000

7. An investment of $230,000 will pay an annual annuity of $45,600 over a six-year period. If the MARR is 8%, is the investment acceptable?

(A) acceptable, $i > 8\%$

(B) not acceptable, $6\% < i < 8\%$

(C) not acceptable, $4\% < i < 6\%$

(D) not acceptable, $i < 4\%$

SOLUTIONS

1. The total annual cost for electricity is

$$\frac{\left(2.6\times 10^4\ \frac{\text{N·m}}{\text{s}}\right)\left(\frac{\$0.10}{\text{kW·hr}}\right)\left(8760\ \frac{\text{hr}}{\text{yr}}\right)}{\left(\frac{1000\ \frac{\text{N·m}}{\text{s}}}{\text{kW}}\right)\left(\frac{87\%}{100\%}\right)} = \$26{,}179/\text{yr}$$

Calculate the total present worth of the annual cost using the uniform series present worth factor. [Economics]

$$P = (P/A,\ i\%,\ n)A$$

Find the present worth for $i = 8\%$ and $n = 5$ yr. [Factor Table]

$$P = (3.9927)(\$26{,}179) = \$104{,}525 \quad (\$105{,}000)$$

The answer is (B).

2. The gradient is uniform at $3000/yr with a recurring annual cost of $42,000. [Economics] [Factor Table]

$$\begin{aligned} P &= (P/A,\ 6\%,\ 8\ \text{yr})A + (P/G,\ 6\%,\ 8\ \text{yr})G \\ &\quad + \text{first year cost} + \text{capital cost} \\ &\quad - (P/F,\ 6\%,\ 8\ \text{yr})F \\ &= (6.2098)(\$43{,}000) + (19.8416)(\$3000) \\ &\quad + \$42{,}000 + \$1{,}500{,}000 \\ &\quad - (0.6274)(\$130{,}000) \\ &= \$1{,}786{,}980 \quad (\$1{,}800{,}000) \end{aligned}$$

The answer is (B).

3. Calculate the financed amount.

$$\$560{,}000 - (0.10)(\$560{,}000) = \$504{,}000$$

Use the uniform series present worth factor to find the effective interest rate. [Economics]

$$\begin{aligned} &(P/A,\ i\%,\ 60\ \text{mo}) \\ &\frac{P}{A} = \frac{\$504{,}000}{\$12{,}700} = 39.6850 \end{aligned}$$

Use factor tables to find i for $P/A = 39.6850$ and $n = 60$.

Using a factor table, $i = 1.50\%$ at 60 months gives $P/A = 39.3803$.

Using a factor table, $i = 1.00\%$ at 60 months gives $P/A = 44.9550$.

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The desired value lies between 1.00% and 01.50 %. By interpolation,

$$\begin{aligned} i &= 1.00\% + \frac{(1.50\% - 1.00\%)(39.6850 - 44.9550)}{39.3803 - 44.9550} \\ &= 1.4727\% \quad (1.47\%) \end{aligned}$$

The answer is (C).

4. For continuous compounding, calculate the annual effective interest rate.

$$i_e = e^i - 1 = e^{0.06} - 1 = 0.06184$$

Calculate the monthly interest rate.

$$i_{\text{monthly}} = \frac{0.06184}{12} = 0.005153$$

Use the capital recovery formula to calculate the annual cost. [Economics]

$$\begin{aligned} A &= \frac{i(1+i)^n}{(1+i)^n - 1} P \\ &= \left(\frac{(0.005153)(1 + 0.005153)^{60}}{(1 + 0.005153)^{60} - 1} \right)(\$280{,}000) \\ &= \$5{,}437 \quad (\$5{,}440) \end{aligned}$$

The answer is (C).

5. The gradient is not uniform, so the uniform annual cost needs to be calculated for each year. Calculate the total present value then calculate the uniform annual cost based on the total present value. The first-year operating cost is not realized until the end of the year. [Economics]

$$P = (P/F,\ 4\%,\ x\ \text{yr})F$$

Using a factor table, for $i = 4\%$,

year 1: $P = (0.9615)(\$430{,}000) = \$413{,}445$

year 2: $P = (0.9246)(\$440{,}000) = \$406{,}824$

year 3: $P = (0.8890)(\$480{,}000) = \$426{,}720$

year 4: $P = (0.8548)(\$510{,}000) = \$435{,}948$

year 5: $P = (0.8219)(\$560{,}000) = \$460{,}264$

Calculate total present value.

$$\begin{aligned} P &= \$7{,}800{,}000 + \$413{,}445 + \$406{,}824 \\ &\quad + \$426{,}720 + \$435{,}948 + \$460{,}264 \\ &= \$9{,}943{,}200 \end{aligned}$$

Calculate the uniform annual cost. [Economics]

$$A = (A/P,\ 4\%,\ 15\ \text{yr})P$$

Using a factor table, for $i = 4\%$,

$$A = (0.0899)(\$9{,}943{,}200) = \$893{,}894 \quad (\$894{,}000)$$

The answer is (C).

6. For alternative 1, the present worth can be calculated using the following equation. [Economics]

$$\begin{aligned} P &= \text{capital cost} + (P/A,\ 4\%,\ 15\ \text{yr})A \\ &\quad + (P/G,\ 4\%,\ 15\ \text{yr})G \end{aligned}$$

The first-year operation and maintenance cost is reduced by 5% to represent the base annual cost.

Using a factor table, for $i = 4\%$,

$$\begin{aligned} P &= \$1{,}200{,}000 + (11.1184) \\ &\quad \times \big(\$140{,}000 - (0.05)(\$140{,}000)\big) \\ &\quad + (69.7355)\big((0.05)(\$140{,}000)\big) \\ &= \$3{,}166{,}900 \end{aligned}$$

For alternative 2, the present worth can be calculated using the following equation. [Economics]

$$\begin{aligned} P &= \text{capital cost} + (P/A,\ 4\%,\ 15\ \text{yr})A \\ &\quad + (P/G,\ 4\%,\ 15\ \text{yr})G \end{aligned}$$

The first-year operation and maintenance cost is reduced by 5% to represent the base annual cost.

Using a factor table, for $i = 4\%$,

$$\begin{aligned} P &= \$1{,}600{,}000 + (11.1184)\big(\$95{,}000 - (0.05)(\$95{,}000)\big) \\ &\quad + (69.7355)\big((0.05)(\$95{,}000)\big) \\ &= \$2{,}934{,}680 \end{aligned}$$

The cost difference between the two alternatives is

$$\$3{,}166{,}900 - \$2{,}934{,}680 = \$232{,}220 \quad (\$232{,}000)$$

The answer is (C).

7. Calculate the interest rate for a term of six years using the uniform series present worth. [Economics]

$$P/A = (P/A,\ i\%,\ 6) = \frac{\$230{,}000}{\$45{,}600} = 5.04386$$

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