Worked out solutions for selected 2014 high school TEAMS competition scenarios

Engineering Digital Relays for Smart Electrical Grids Solutions

Solutions

11. Answer Choice: d. 682 kV
    Solution:

$$P = \frac{(\text{D}V)^2}{R}$$

$$(\text{D}V)^2 = P \times R$$

$$(\text{D}V)^2 = 3100 \text{ MW} \times 150 \text{ W}$$

$$(\text{D}V)^2 = 465{,}000{,}000{,}000$$

$$V = \sqrt{465{,}000{,}000{,}000}$$

$$V = 681{,}909 \text{ V}$$

$$V \approx 682 \text{ kV}$$

12. Answer Choice: a. 0.001 Ω
    Solution:

$$R_2 = \frac{R_1}{\left(\frac{V_{IN}}{V_{OUT}} - 1\right)}$$

$$R_2 = \frac{150 \text{ W}}{\left(\frac{682 \text{ kV}}{5 \text{ V}} - 1\right)}$$

$$R_2 = \frac{150 \text{ W}}{(136{,}399)}$$

$$R_2 = 0.001 \text{ W}$$

13. Answer Choice: b. NAND
    Solution:

Type	Transmission Line Input	5 V Input	Gate Output	LOGIC
AND	1	1	1	Gate **will** activate LED and circuit breaker even when no fault is present.

	0	1	0	Gate **will not** activate LED and circuit breaker when fault is present.
NAND	1	1	0	Gate **will not** activate LED and circuit breaker when no fault is present.
	0	1	1	Gate **will** activate LED and circuit breaker when fault is present.
OR	1	1	1	Gate **will** activate LED and circuit breaker even when no fault is present.
	0	1	1	Gate **will** activate LED and circuit breaker when fault is present.
NOR	1	1	0	Gate **will not** activate LED and circuit breaker when no fault is present.
	0	1	0	Gate **will not** activate LED and circuit breaker when fault is present.
EX-NOR	1	1	1	Gate **will** activate LED and circuit breaker even when no fault is present.
	0	1	1	Gate **will** activate LED and circuit breaker when fault is present.

14. Answer Choice: d. 6,324 A
    Solution:

$$P = I^2 \times R$$

$$4000 \text{ MW} = I^2 \times 100 \text{ W}$$

$$I^2 = \frac{4000 \text{ MW}}{100 \text{ W}} = \frac{4 \times 10^9 \text{ W}}{100 \text{ W}}$$

$$I^2 = 40{,}000{,}000$$

$$I = \sqrt{40{,}000{,}000}$$

$$I \approx 6{,}325 \text{ A}$$

15. Answer Choice: c. 77 MW
    Solution:

$$V_{OUT} = \frac{R_2}{R_1 + R_2} \times V_{IN}$$

$$0.7 \text{ V} = \frac{0.0008 \text{ W}}{100.0008 \text{ W}} \times V_{IN}$$

$$0.7 \text{ V} = 0.000008 \times V_{IN}$$

$$V_{IN} = \frac{0.7 \text{ V}}{0.000008}$$

$$V_{IN} = 87{,}500 \text{ V}$$

$$P = \frac{(\text{D}V)^2}{R} = \frac{7{,}656{,}250{,}000 \text{ V}^2}{100 \text{ W}}$$

$$P = 76{,}562{,}500 \text{ W} \approx 77 \text{ MW}$$

16. Answer Choice: d. 2 hours
    Solution: Given that 1 MW can sustain 1000 homes for 1 h, 77 MW can sustain 77,000

homes for 1 h or 38,500 homes for 2 hours.

17. Answer Choice: e. Replace the relay resistor (R_2) so V_{OUT} is reduced at a higher wattage level during the fault.
    Solution: Logic behind incorrect answers
    a. A logic gate does not increase the voltage of its input. (Use another type of logic gate with an output that will increase the voltage level of its input.)
    b. This will not affect the input from the transmission line. (Replace the logic gate power supply with one that will input 0.7 V instead of the nominal 5 V.)
    c. Changing the voltage will change the current. (Increase the amount of voltage flowing across the transmission lines, but keep the current stable.)
    d. Changing the current will change the voltage. (Reduce the amount of current flowing through the transmission lines, but keep the voltage stable.)

18. Answer Choice: d. 1333 A
    Solution:

$$I_{TOTAL} = \frac{P}{V} = \frac{2000\ \text{MW}}{500\ \text{kV}} = 4000\ \text{A}$$

$$I_{\text{T3}} = \frac{4000\ \text{A}}{3} \approx 1333\ \text{A}$$

19. Answer Choice: c. Yes, the electric current in T3 will be multiplied by three, but this value is still lower than its maximum capacity of 5000 A.
    Solution:

$$I_{TOTAL} = \frac{P}{V} = \frac{2000\ \text{MW}}{500\ \text{kV}} = 4000\ \text{A}$$, 4000 A < 5000 A

20. Answer Choice: a. Silver conducts an electric charge better than copper.
    Solution:

$$\rho_{COPPER} = \frac{\text{resistivity-density product}}{\text{density}} = \frac{150}{8.96} = 16.74\ \text{n}\Omega \cdot \text{m}$$

$$\sigma_{COPPER} = \frac{1}{\rho} = \frac{1}{16.74} = 0.0597\ \text{S/m}$$

$$\rho_{SILVER} = \frac{166}{10.49} = 15.82\ \text{n}\Omega \cdot \text{m}$$

$$\sigma_{SILVER} = \frac{1}{15.82} = 0.0632\ \text{S/m}$$

$$\sigma_{SILVER} > \sigma_{COPPER}$$

Urban Green Space Design Solutions

51. The GS_C added due to the proposed project on a square foot per capita basis is closest to:

a. 14 b. 22 c. 1 d. 8 e. 32

ANSWER: d

SOLUTION: First find the added square footage of each corridor.

$$Area\ Corridor\ 1 = (6300ft * 21ft) = 132{,}300\ ft^2$$
$$Area\ Corridor\ 2 = (16380ft * 15ft) = 245{,}700\ ft^2$$
$$Area\ Corridor\ 3 = (3696ft * 24ft) = 88{,}704\ ft^2$$
$$Area\ Corridor\ 4 = (520ft * 25ft) = 13{,}000\ ft^2$$
$$Area\ Corridor\ 5 = (8976ft * 17ft) = 152{,}592 ft^2$$

The sum of individual corridor areas is:

132,3000 ft^2 + 245,700 ft^2 + 88,704 ft^2 + 13000 ft^2 + 152,592 ft^2 = 632,296 ft^2

The GS_C is then:

$$\frac{632{,}296\ ft^2}{81{,}247\ \ persons} = 7.78\ ft^2$$

The result is closest to 8 square ft per capita

52. If the proposed corridor project is developed, what additional minimum amount of green space would need to be developed in the future to meet the GS_C requirement of 1 acre for every 200 residents?

a. 21 acres b. 6 acres c. 40 acres d. 100 acres e. 60 acres

ANSWER: a.

SOULTION:
Step 1. Determine the total amount of acreage required for the population at the GSC requirement:

$$\frac{1\ acre}{200\ residents} = \frac{x\ acres}{81{,}247\ residents}$$

$$\therefore x = 406.24\ acres$$

Step 2. Compare the current amount of acreage to the requirement to find the amount of additional acres required.

406.24 acres – 371 acres = 35. 235 additional acres required.

Step 3. Determine the amount of acreage contained within the individual corridors.

$$Area\ Corridor\ 1 = (6300ft^2 * 21ft)\frac{1\ acre}{43560\ ft^2} = 3.04\ acres$$

$$Area\ Corridor\ 2 = (16380ft^2 * 15ft)\frac{1\ acre}{43560\ ft^2} = 5.64\ acres$$

$$Area\ Corridor\ 3 = (3696ft^2 * 24ft)\frac{1\ acre}{43560\ ft^2} = 2.04\ acres$$

$$Area\ Corridor\ 4 = (520ft^2 * 25ft)\frac{1\ acre}{43560\ ft^2} = 0.30\ acres$$

$$Area\ Corridor\ 5 = (8976ft^2 * 17ft)\frac{1\ acre}{43560\ ft^2} = 3.50\ acres$$

Step 4. Sum the acreage of individual corridors to come up with a total acreage

3.04 + 5.64 + 2.04 + 0.30+ 3.50 = 14.52 acres.

Step 5. Subtract 35.24 acres needed from 14.52 acres new development to find 20.72 acres more needed.

53. The percent decrease of GS_P due to the proposed project is closest to:

a. 15% d. 63%
b. 57% e. 77%
c. 82%

ANSWER: b

SOLUTION: Current GSD is 2200 ft
New GSD following development is 975 ft

% decrease due to development is

$$\left[\frac{(2200-975)}{2200}\right] * 100 = 55.7\%$$

54. Using the data found in Table 1 and the planned percent of the new development that will be unmaintained landscape, the total acreage of undeveloped habitat area based upon the proposed development is:

a. 6.0 d. 12.8
b. 22.7 e. 2.7
c. 14.5

ANSWER: a

SOLUTION

A total of 14.52 acres of new green corridor is planned. If the corridor is 41% unmaintained land, then the amount of undeveloped habitat area is 14.52*0.41 = 5.95%

55. If one section of the development replaces a 300 ft segment of a 4 ft wide concrete side walk with a gravel path, the anticipated decrease in runoff volume for a 1 inch precipitation event is approximately:

a. 5 ft^3
b. 30 ft^3
c. 250 ft^3
d. 60 ft^3
e. 120 ft^3

ANSWER: d

SOLUTION:

The volume of runoff from concrete sidewalk is:

$$V = 1200ft^2 * \left(\frac{\left[1 - 0.2\left(\frac{1000}{98} - 10\right)\right]^2}{1 + 0.8\left(\frac{1000}{98} - 10\right)}\right)\left(\frac{1\,ft}{12\,in}\right) = 79.16\,ft^3$$

The volume of runoff from gravel sidewalk is:

$$V = 1200ft^2 * \left(\frac{\left[1 - 0.2\left(\frac{1000}{85} - 10\right)\right]^2}{1 + 0.8\left(\frac{1000}{85} - 10\right)}\right)\left(\frac{1\,ft}{12\,in}\right) = 17.36\,ft^3$$

The difference between the two volumes is 79.16 – 17.36 = 61.8, which is close to 60 ft^3

56. By examining the SCS runoff volume equation, a relationship between CN and runoff volume can be inferred. If the CN decreases, the runoff volume will:

a. increase only if precipitation increases
b. decrease only if precipitation increases
c. increase regardless of precipitation
d. decrease regardless of precipitation
e. not change

ANSWER: d
SOLUTION: as CN gets smaller the runoff volume decreases regardless of precipitation

57. They city engineers estimated the total construction costs for the proposed project to be $5 million. If the project has a 20 year service lifespan (the amount of time the project will be used and maintained) and an annual interest rate of 8% compounded yearly is assumed, the annualized cost of the construction portion over the 20 year timeframe is closest to:

a. - $500,000 d. - $100,000
b. - $250,000 e. - $1,000,000
c. - $750,000

ANSWER: A

SOLUTION: $A_P = -5x10^6 \left[\frac{0.08}{1-(1+0.08)^{-20}}\right]$ = -$509,261 /yr

58. The city engineers also plan a one-time cost to completely re-gravel the entire corridor during year 10 of the projects anticipated lifetime. The engineers estimated the cost of the re-gravelling effort 10 years from now to be $750,000. If the project has a lifespan of 20 years and an annual interest rate of 8% compounded yearly is assumed, the annualized cost of the future re-graveling effort is approximately:

a. - $10,000
b. - $20,000
c. - $90,000
d. - $75,000
e. - $35,000

ANSWER: E

SOLUTION: $A_F = -\$750{,}000 \left[\frac{1}{(1+0.08)^{10}}\right] * \left[\frac{0.08}{1-(1+0.08)^{-20}}\right] = -\$35{,}383\ /yr$

59. The city planning commission received a bid from a construction firm that estimated the initial cost of the gravel path installation to be 1.5 million US dollars. The bid also included a re-graveling cost of 700,000 dollars in year 10. The company also included a cost estimate for a gravel path maintenance cost of $50,000 per year and a routine inspection cost of $5,000 per year. Based upon these cost projections, the annual worth of the project is:

a. - $182,000/yr
b.- $94,000/yr
c. - $68,000/yr
d. - $241,000/yr
e. - $72,000/yr

ANSWER: D

SOLUTION:

First solve for A_P

$A_P = -1.5x10^6 \left[\frac{0.08}{1-(1+0.08)^{-20}}\right]$=-$152,778

Next solve for A_F

$$A_F = -\$700{,}000 \left[\frac{1}{(1+0.08)^{10}}\right] * \left[\frac{0.08}{1-(1+0.08)^{-20}}\right] = -\$33{,}024\ /yr$$

Next sum up Annual Operating Costs

-50,000 + -5000 = -55000

Finally add AP + AF + AOC = -152,778 – 33,024 - 55000 = -$240,802

60. The city planning commission received a second bid with an annual worth projection of - $138,000 per year. If the project is developed, the city expects $60,000 per year of revenues from increased amphitheater sales and $27,000 per year revenue from increased festival related sales. The city also expects to generate increased revenue from property taxes, as property values surrounding green spaces increase. How much annual tax revenue must the project generate each year to pay for itself?

a. + $160,000
b. - $51,000
c. - $72,000
d. + $51,000
e. + $72,000

ANSWER: D

SOLUTION: Add each of the proposed annual revenues from the AW projection to determine the annual surplus or shortfall.

-138,000 + 60,000 + 27,000= -51,000.

That means that the annual tax revenue must be at least +51,000 to break even.

Water and Wastewater Systems Solutions

61. CRMWD has a water tank in the shape of an inverted cone. The radius of the base of the cone is 3 meters and the height of the cone is 6 meters. Water is pumped into the tank at a rate of 2 m^3 /min. What is the rate at which water is rising when the water is 3 m deep?

    a. 7.07
    b. 0.28
    c. 2.00
    d. 2.82
    e. 0.61

Answer: b
Let r = radius of surface of water, h = height of water at time t.
Using similar triangles, r / h = 3 / 6
or r = h/2
The expression for V becomes
V = 1/3 π $(h/2)^2$ h = π/12 h^3
Differentiating each side with respect to t we get:
dv/dt =(π/4) h^2 dh/dt
or dh/dt = 4/(π h^2) dv/dt
Substituting h = 3m and dv/dt = 2 m^3 /min.
we get dh/dt = 4 / π $(3)^2$ x 2 = 8 / 9 π = .28 m/min.

62. Find the velocity of water in a pipe of 24" diameter and flow rate is 11 cfs.

    a. 0.02
    b. 34.54
    c. 3.5
    d. 0.29
    e. 0.08

Answer: c
Change the diameter from inches to feet: 24"= 2 feet.
Area of pipe in square feet = π r^2 = π x 1 x 1 = 3.14 sq. ft.
Velocity in fps = 11 cfs/ 3.14 sq.ft. = 3.5 fps

63. CRMWD has a tank that is 100 feet in diameter and 22 feet high. If the flow into the tank is 1500 gallons per minute (gpm) and the flow out of the tank is 300 gpm, how many hours will it take to fill the tank?

    a. 1077
    b. 14.33

c. 860
d. 17.95
e. 115.2

Answer: d

Volume in cubic feet = $\pi r^2 h = \pi \times 50 \times 50 \times 22 = 172{,}788\ ft^3$

Change cubic feet to gallons:

$172{,}800 \times 7.48\ ft^3 = 1{,}292{,}451$ gallons

Net inflow = 1500 gpm – 300 gpm = 1,200 gpm

Time to fill = 1,290,000/1,200 = 1077 minutes = 1075/60 = 17.95 hours

64. CRMWD has a tank that is 44' in diameter and 22' high. It is dosed with 50 ppm of chlorine. How many pounds of chlorine are needed?

a. 104.34
b. 208.68
c. 313.02
d. 52.17
e. 10,434

Answer: a

Volume in cubic feet = $\pi r^2 h = \pi \times 22 \times 22 \times 22 = 33{,}452\ ft^3$

Change cubic feet to gallons:

33,450 x 7.48 = 250,218 gallons

Change gallons to millions of gallons:

250,000 gallons = 0.25 millions of gallons

Find lbs. of chlorine:

50 ppm x 0.25 x 8.34 = 104.34 lbs of chlorine

65. There are 120 homes on a CRMWD system and the average daily consumption is 350 gallons per house. The chlorine dosage is 1.3 ppm. How many pounds of chlorine must be purchased each year?

a. 0.45
b. 166.2
c. 455,364
d. 1247.57
e. 3.42

Answer: b

System consumption:

120 houses x 350 gallons/day/house = 42,000 gpd

Change gpd to mgd:

42,000 gpd = 0.042 mgd

Pounds of chlorine per day:
1.3 ppm x 0.042 mgd x 8.34 = 0.45 lbs/day
Find lbs/year:
0.45 lbs/ day x 365 = 166.2 lbs. / year

66. CRMWD has an electric pump requires 12.5 kw (kilowatt) of electricity. If the pump runs 13 hours a day and electric rates are $0.09/kwh (kilowatt hour), how much does it cost to run the pump for a year (365 days)?

    a. 14.625
    b. 1462.50
    c. 5338.13
    d. 146.25
    e. 53,381.25

Answer: c
Find kwh per day
12.5 kw x 13 hours/day = 162.5 kwh/day

Find cost per day
162.5 kwh x $0.09/kwh = $ 14.625/day

Find cost for the year
$14.58/day x 365 = $ 5338.13/year

67. If 11 kW of power is supplied to a CRMWD motor, and the brake hp is 13, what is the efficiency of the motor?

    a. 84.62
    b. 90.29
    c. 88.00
    d. 15.47
    e. 64.64

Answer: b
Convert kW to hp:
11kW/ (0.764 kW/hp) = 14.40 hp
Percent efficiency = 13/14.75 x 100 = 90.29 %

68. A CRMWD employee receives an hourly wage of $17.50. For each hour worked over 40 hours per week, overtime is paid at 1.5 times the hourly rate. If the employee works 52 hours during a week, what is the employee's total pay for that week?

    a. 910
    b. 1365
    c. 1015
    d. 700
    e. 315

Answer: c

Overtime hours = Total hours – Regular hours

= 52 – 40 = 12 hours overtime

Regular pay = 40 hours x $17.50/hour = $ 700.00

Overtime wage = $ 17.50/hour x 1.5 = $26.25/hour

Overtime pay = 12 hours x $26.25/hour = $315.00

Total pay = Regular Pay + Overtime Pay = $700 + $315 = $1,015.00

69. CRWD wants to make a gravel border of uniform width around a small water tank. The tank is 10 feet by 6 feet. They have enough gravel to cover 36 square feet. How wide should the border be?

    a. 1.125 ft.
    b. 0.69 ft.
    c. 1.2 ft.
    d. 1.1 ft
    e. 1 ft.

Answer: e

Area of tank = (6) (10) = 60 square feet

Area of larger rectangle = (6 + 2x) (10 + 2x) square feet

The difference should be 36 square feet.

$(6 + 2x)(10 + 2x) - 60 = 36$

$60 + 32x + 4x^2 - 60 = 36$

$4x^2 + 32x - 36 = 0$

$x^2 + 8x - 9 = 0$

$(x + 9)(x - 1) = 0$

The solutions are -9 and 1.

The number -9 cannot be the width of the border.

So the solution is to make the border 1 foot wide.

70. A rectangular protective tank enclosure is to be built with three sides made of steel fencing at a cost of $15 per running foot, and the road side made of brick at a cost of $30 per running foot. $ 900 is available for the project. What are the dimensions with maximum possible area?

    a. 12 ft. by 12 ft.
    b. 10 ft. by 10 ft.
    c. 10 ft. by 15 ft.
    d. 12 ft. by 13 ft.
    e. 11 ft. by 14 ft.

Answer: c

Let x represent the parallel steel fencing sides.
Let y represent the parallel steel and brick fencing sides.
$15x + 15x + 15y + 30y = 900$
$30x + 45y = 900$
$45y = 900 – 30x$
$Y = 20 – 2x/3$
Area = x. y = $x(20 – 2x/3)$
$=20x – 2x^2/3$
$= -2/3\ (x^2 – 30x)$
$= -2/3\ (x^2 -30x +255 – 255)$
$= -2/3\ (x^2 -30x +255) + (-2/3)\ (-255)$
$= -2/3(x-15)^2 + 150$
The maximum occurs when $x = 15$
If $x = 15$,
$y = 20 – 2/3\ (15) = 10$
The dimensions of the enclosure are 10 feet by 15 feet.