2014 TEAMS Middle School Competition Solutions

Questions

1. What is the flow of current when a lamp containing a 60-watt bulb is plugged into a standard U.S. outlet?
    a. 6600 volts
    b. 5.5 volts
    c. 0.66 amps
    d. 0.55 amps
    e. 6600 amps

Solution: Use the equation $P = IV$ where *P* is given as 60 watts, *V* is given as 110 volts. Solving for *I*, which will be in amps:

$$P = IV$$

$$60 \text{ W} = I(110 \text{ V})$$

$$\frac{60}{110} = 0.54545454... \approx 0.55 \text{ A}$$

2. Theoretically, how many lamps like that in question *1* could be on the same circuit before tripping the 15-amp circuit breaker?
    a. 5 lamps
    b. 15 lamps
    c. 20 lamps
    d. 27 lamps
    e. 55 lamps

Solution: The 60 W bulb uses 0.55 A. The total number of lamps must use under 15 A.

$$\frac{15 \text{ A}}{0.55 \text{ A}} \approx 27; \quad \text{Check: } 27 \times 0.55 = 14.85$$

Using 28 lamps on the circuit will trip the breaker.

3. How much power is generated by the number of lamps calculated in question 2?
    a. 0.165 watts or less
    b. 1400 watts or more
    c. 1650 watts or less
    d. 0.14 watts or less
    e. 1650 watts or more

Solution: Use the equation $P = IV$ where *I* is given as the total current from question 2 in amperes, the potential difference is given as 110 volts. Solving for *P*, in watts gives:

$$P = IV$$

$$P = (14.85 \text{ A})(110 \text{ V})$$

$$P = 1633.5 \text{ W}$$

4. A hair dryer draws a current of 10 A on its "Hot" setting and a current of 4 A on its "Cool" setting. What percent decrease in power occurs when you switch the hair dryer from the "Hot" setting to the "Cool" setting?

a. 60% *
b. 150%
c. 0.6%
d. 15%
e. −150%

Solution: Use the equation $P = IV$ to find the power drawn by the hair dryer on "Hot."

$$P = IV$$

$$P = (10 \text{ A})(110 \text{ V}) = 1100 \text{ W}$$

Next, use the equation again to find the power drawn by the hair dryer on "Cool."

$$P = IV$$

$$P = (4 \text{ A})(110 \text{ V}) = 440 \text{ W}$$

Finally, compute the percent decrease in power using the formula provided:

$$\text{Percent decrease} = \frac{\text{original value} - \text{new value}}{\text{original value}} \times 100$$

$$= \frac{1100 - 440}{1100} \times 100$$

$$= 60\%$$

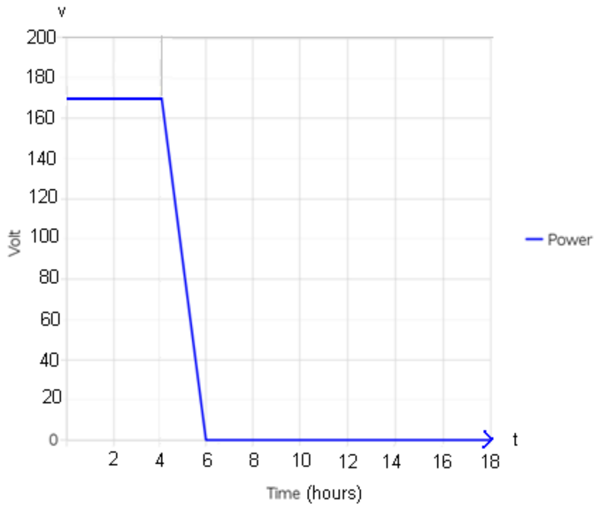
Therefore, there is a 60% decrease in power.

5. Referring to the graph of a transient fault, about how much power was the electrical line carrying before the fault occurred?

a. 200 V
b. 228 V
c. 0 V
d. 50 V
e. 250 V

Solution: Looking at the graph line, it starts above the halfway point between 200 volts and 250 volts. The closest answer choice is 228 volts for *time* = 0 until the transient fault occurred.

6. Which of the following piecewise functions best describes the graph of the blackout event shown below?



a. $f(t) = \begin{cases} 170 \text{ if } 0 \le t < 4 \\ -85t + 510 \text{ if } 4 \le t < 6 \\ 0 \text{ if } t \ge 6 \end{cases}$

b. $f(t) = \begin{cases} 170 \text{ if } t < 4 \\ 85t - 510 \text{ if } 4 \le t < 6 \\ 0 \text{ if } t \ge 6 \end{cases}$

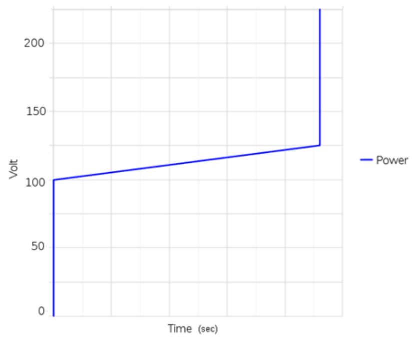
c. $f(t) = \begin{cases} 170 \text{ if } 0 \le t \le 4 \\ -85t + 510 \text{ if } 4 \le t \le 6 \\ 0 \text{ if } t \ge 6 \end{cases}$

d. $f(t) = \begin{cases} 170 \text{ if } t \le 4 \\ 85t - 510 \text{ if } 4 < t \le 6 \\ 0 \text{ if } t > 6 \end{cases}$

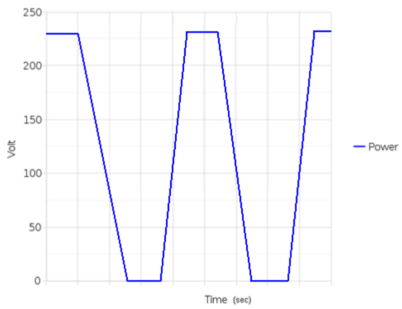
Solution: The leftmost piece of the graph is the horizontal line at $V = 170$, the middle segment of the graph is the line $V = -85t + 510$, which is found by using endpoints (4, 170) and (6, 0) and the rightmost segment of the graph is the horizontal line at $V = 0$.

7. Which of the following graphs shows what a typical brownout would look like in terms of power supply over time?

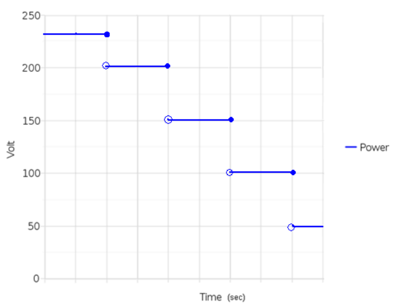
a.



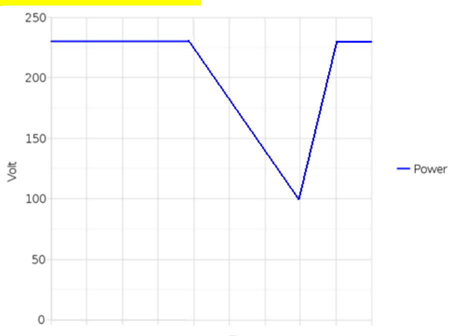
b.



c.



d. Correct answer:



8. Based on the information provided, why would a silver ground wire be chosen over a copper one?
   a. Silver conducts an electric charge better than copper.
   b. Silver has a higher density than copper.
   c. Silver has a higher Resistivity-density product than copper.
   d. Silver is more resistive than copper.

Solution:

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

$$s_{COPPER} = \frac{1}{r} = \frac{1}{16.74} = 0.0597 \text{ S/m}$$

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

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

$$s_{SILVER} > s_{COPPER}$$

9. What resistance would be required in the circuit, or network, shown?

    a. 960 ohms
    b. 12 ohms
    c. 15 ohms
    d. 0.07 ohms
    e. 8 ohms

Solution: To find resistance, first solve the Ohm's Law equation, $I = \frac{V}{R}$, for resistance (*R*).

$$I = \frac{V}{R}$$

$$I \times R = \frac{V}{R} \times R$$

$$\frac{I \times R}{I} = \frac{V}{I}$$

$$R = \frac{V}{I}$$

Next, substitute the known values for voltage and current into the new rearranged equation.

$$R = \frac{120 \text{ V}}{8 \text{ A}}$$

$$R = 15 \text{ ohms, or } 15 \text{ W}$$

Therefore, the resistance in the circuit is 15 ohms.

10. Using the information in the Table, which logic gate should be used when designing a properly functioning relay circuit?
    a. AND
    b. NAND
    c. OR
    d. NOR
    e. EX-NOR

11. The residents of Green Acres have set the goal to be living in a zero net energy building by 2020 (to generate as much energy as they use). As a first step, the residents want to reduce the energy use in each apartment from the current average of 450 kWh to 120 kWh. What is the percentage change in energy use for this reduction?

a. −73.3%
b. −7.3%
c. 0%
d. 7.3%
e. 73.3%

Answer: a
Let the new value = 120 kWh and the old value = 450kWh.
By using the formula provided, the answer is

$$\frac{120\text{ kWh} - 450\text{ kWh}}{450\text{ kWh}} \times 100 = -73.3\%$$

12. To achieve the goal of a zero net energy building, Green Acres residents are installing a solar panel array on its roof. The array costs $125,000, and the installation is an additional $2,200. The residents are told that the array will generate the equivalent to $6,800 in electricity every year. If the array is installed in January of 2014, in what year will the residents have recovered its total cost?

a. 2028
b. 2029
c. 2030
d. 2031
e. 2032

Answer: e
The total cost of the solar panel array is $\$125{,}000 + \$2{,}200 = \$127{,}200$. If it generates $6,800 every year, it will take $\frac{\$127{,}200}{\$6{,}800} = 18.7$ years to cover its total cost. This would occur in the year 2032 (2014 + 18.7 = 2032.7 in the middle of September, to be precise).

13. The residents of Green Acres have also decided to install a rainwater catchment system on the roof to reduce their reliance on the city water supply. The designer of the catchment system claims that a 1,000 sq. ft roof can collect up to 600 gallons of water for every inch of rainfall. If Green Acres' roof has an area of 2,550 sq. ft, what is the maximum amount of water it can collect for every inch of rain?

a. 600 gallons
b. 1,530 gallons
c. 2,250 gallons
d. 3,630 gallons
e. 4,250 gallons

Answer: b

Set up this problem by comparing two ratios: one for a 1,000-sq. ft roof and another for a 2,550 sq. ft roof. $\frac{1{,}000 \text{ sq. ft}}{600 \text{ gal}} = \frac{2{,}550 \text{ sq. ft}}{x \text{ gal}}$. Solving this equation for *x*, the Green Acres' roof can collect 1,530 gallons of water for every inch of rain.

14. The solar panel array on the roof prevents Green Acres from using the entire roof to collect rainwater. Two rectangular areas have been set aside for rainwater catchment. The first is length of 32 ft long and a 5 ft wide, and the second is 14 ft long and of 17 ft wide. Each square foot of the catchment system can collect 0.6 gallons of water for every inch of rain. What is the maximum amount of water Green Acres can collect for every inch of rain?

a. 159.1 gallons
b. 182.4 gallons
c. 202.9 gallons
d. 238.8 gallons
e. 264.1 gallons

Answer: d

First, find the total area of the catchment system by adding the two rectangular areas. The area of the first section is $32 \text{ ft.} \times 5 \text{ ft.} = 160 \text{ sq. ft.}$ The area of the second section is $14 \text{ ft.} \times 17 \text{ ft.} = 238 \text{ sq. ft.}$ The total area of the catchment system is $160 \text{ sq. ft.} + 238 \text{ sq. ft.} = 398 \text{ sq. ft.}$ Because each square foot can capture 0.6 gallons of water, the maximum that this system can collect for each inch of rain is $398 \text{ sq. ft.} \times \frac{0.6 \text{ gallons}}{1 \text{ sq. ft.}} = 238.8 \text{ gallons.}$

15. One important concept for a zero net energy building is the idea of "net energy". Even though Green Acres may use more energy during the winter, it will produce more energy during the summer, so that over the course of the year the total (net) energy consumed is equal to zero. The table below lists the energy (in kWh) the residents' used each month.

Month	**Energy usage (kWh)**
January	105,000
February	112,000
March	69,000
April	42,000
May	21,000
June	-
July	-
August	-
September	19,000
October	39,000
November	56,000
December	81,000

June, July, and August are the sunny, summer months when Green Acres produces all of its energy from its solar panel array along with some extra energy that it stores. The solar array does not produce sufficient energy during the rest of the year to meet the residents' needs. If Green Acres is to have zero net energy for this calendar year, how much extra energy does it need to produce during the summer?

a. 19,000 kWh
b. 74,000 kWh
c. 112,000 kWh
d. 356,000 kWh
e. 544,000 kWh

Answer: e
The extra energy produced during the summer must equal the amount of energy used during the rest of the year. Determine the value of this energy by summing the energy usage for each month shown, which gives 544,000 kWh. This result means that during the summer Green Acres must produce 544,000 kWh to have zero net energy usage for the year.

16. Passive solar heating is the use of design features to capture the energy from the sun in order to heat a building for free. The south-facing side of Green Acres (which gets the most sunlight) has 14 residential units, and these residents are considering the installation of floor-to ceiling windows to capture the most light. If each unit has a 9 ft. ceiling and a south-facing wall that is 19 ft long, how much glass will they need to order to make this design change?

a. 171 sq. ft.
b. 1,522 sq. ft.
c. 2,394 sq. ft.
d. 2,911 sq. ft.
e. 3,569 sq. ft.

Answer: c
Calculate the amount of glass needed for each unit. If the south-facing wall of a unit is 19 ft by 9 ft then $19\text{ ft} \times 9\text{ ft} = 171\text{ sq. ft}$ of glass would be needed for each unit. Because there are 14 units, $\frac{171\text{ sq. ft}}{\text{unit}} \times 14\text{ units} = 2{,}394\text{ sq. ft}$ of glass needs to be ordered.

17. Even with a passive solar design, traditional glass windows are a main source of heat loss in modern buildings, especially during winter months. Each window in a unit at Green Acres has an area of 1.2 m^2 and is 0.04 m thick. If the average temperature inside the unit is kept at 22°C and the average temperature outside is 4°C during the winter, what is the rate of heat transfer through this window?

a. 78.6 W
b. 92.2 W
c. 108.2 W
d. 131.9 W
e. 145.8 W

Answer: e
Identify the values given in the question with the variables in the heat transfer equation.
k = 0.27 W/m/°C

A = 1.2 m^2
T_1 = 22°C
T_2 = 4°C
d = 0.04 m
Then, substitute these values into the equation to determine the rate of heat transfer through the window.

$$0.27 \frac{\frac{\text{W}}{\text{m}}}{°\text{C}} \times 1.2\ \text{m}^2 \times \frac{22\ °\text{C} - 4\ °\text{C}}{0.04\ \text{m}} = 145.8\ \text{W}$$

18. Green Acres residents are also implementing methods to reduce the amount of trash that they produce. They are composting food waste rather than throwing it in the garbage. The residents estimate that 25% of their trash is food waste. There are 42 units in Green Acres, and each unit produces 135 pounds of trash per month. If each unit composted half of their food waste, how much trash would be eliminated by the community every month?

a. 429.93 lbs.
b. 515.20 lbs.
c. 664.39 lbs.
d. 708.96 lbs.
e. 772.18 lbs.

Answer: d
Calculate the amount of trash that would be eliminated for one unit. If a unit composts half of its food waste, this would be equivalent to $25\% \times \frac{1}{2} = 12.5\%$ of the total trash. Because each unit produces 135 pounds of trash per month, this is equivalent to eliminating $135\ \text{lbs.} \times 12.5\% = 16.88\ \text{lbs.}$ of trash every month. If all 42 units eliminate this much trash, then every month the community as a whole would eliminate $16.88\ \frac{\text{lbs.}}{\text{unit}} \times 42\ \text{units} = 708.96\ \text{lbs.}$

19. Many residents at Green Acres drive their cars to work every day. In an effort to reduce carbon emissions, the residents are setting up a car-pooling system. Each resident that drives produces 7,500 lbs. of CO_2 every year by driving to work alone. A consultant told the residents that the entire Green Acres complex produces 2,000,000 kilograms of CO_2 every year. If the residents want to reduce their annual CO_2 emissions by 3.2% using the car-pooling system, how many residents must leave their cars at home and car pool to work?

a. 18
b. 19
c. 20
d. 21
e. 22

Answer: b
Calculate the weight of CO_2 the residents produce each year using the given conversion factor: $2{,}000{,}000\ \text{kg} \times \frac{2.2\ \text{lbs.}}{1\ \text{kg}} = 4{,}400{,}000\ \text{lbs.}$ The residents want the car-pooling system to reduce this amount by 3.2%, which is equivalent to $4{,}400{,}000\ \text{lbs.} \times 3.2\% = 140{,}800\ \text{lbs.}$ If each resident who leaves his or her car at home saves 7,500 lbs. of CO_2, then the number of residents needed to meet this goal is

$140{,}800 \text{ lbs.} \times \frac{1 \text{ resident}}{7{,}500 \text{ lbs.}} = 18.77 \text{ residents.}$ Because we can't have a fraction of a resident, 19 residents must leave their cars at home.

20. One of the perks of generating energy at your residence (using solar panels, wind turbines, etc.) is that any excess energy can be sold back to the utility grid. At the end of the year, Green Acres had generated an excess of 279,000 kWh of energy with their solar panel array. They decided to sell this energy and divide the profits equally among the 108 residents (to be reinvested into home improvements). If the local power company pays $0.09/kWh, how much money will each resident receive?

a. $232.50
b. $256.19
c. $282.60
d. $301.56
e. $314.10

Answer: a
Calculate the value of the excess energy. Because the power company pays $0.09/kWh, and the complex is selling 279,000 kWh, the total amount they will receive is $279{,}000 \text{ kWh} \times \frac{\$0.09}{\text{kWh}} = \$25{,}110$. If this money is divided equally among the 108 residents, each resident will receive $\frac{\$25{,}110}{108} = \$232.50$.

21. An architect is designing a new residential building. The plot of land where the building will be constructed is a square block whose sides have a length of 28 meters (m). The architect is designing the building using a virtual reality modeling system, and she lays a grid over the model plot (with *x* and *y* axes). Each point on the plot can be assigned coordinates (*x*, *y*) (measured in meters).

The architect then has a virtual resident walk the entire perimeter of the plot, from (0,0), to (28, 0), to (28,28), to (0,28), and finally to (0,0). What is the total distance that the virtual resident has walked?

a. 0 m
b. 28 m
c. 56 m
d. 84 m
e. 112 m

Answer: e
The total distance is the sum of the distances walked in each section of the simulation. From (0,0) to (28,0) the resident walks 28 m (in the *x* direction). From (28,0) to (28,28) the resident walks another 28 m (in the *y* direction). From (28,28) to (28,0) the resident walks 28 m (this time in the negative *x* direction). And from (28,0) to (0,0) the resident walks 28 m (this time in the negative *y* direction). The total distance walked is then 28 x 4 = 112 m.

22. Using the same information as in Question 1, what is the total displacement of the virtual resident after walking around the plot?

a. 0 m
b. 28 m
c. 56 m
d. 84 m
e. 112 m

Answer: a
Using the equation for displacement, we can see that x_i, x_f, y_i, and y_f are all 0. That is, the resident begins and ends the walk at the point (0,0). Therefore, the total displacement is 0 m.

23. The developers of the new building want to build a roof garden, which will be shared by the individual residents. They ask the architect to create a diagram of the garden that shows the separate plots for each resident. The section of the roof they have set aside for the garden is a rectangle with a length of 22 m and a width of 8 m. If there will be 142 residents living in the building, how much garden space will each resident get?

a. 0.85 m^2
b. 0.96 m^2
c. 1.11 m^2
d. 1.24 m^2
e. 1.34 m^2

Answer: d
Calculate the total area that will be used for the garden: $22 \text{ m} \times 8 \text{ m} = 176 \text{ m}^2$. This area will be divided equally among the 142 residents, so each resident will get $\frac{176 \text{ m}^2}{142} = 1.24 \text{ m}^2$.

24. On the roof next to the garden, the developers plan to install a rain catchment system. The tank that stores the rainwater will be in the shape of a cylinder. It will be 14 ft tall, but the only space available on the roof is a square space whose sides each measure 8 ft. They ask the architect what is the capacity of the tank?

a. 542.9 ft^3
b. 596.1 ft^3
c. 668.5 ft^3
d. 703.7 ft^3
e. 741.2 ft^3

Answer: d
The cylinder, which has a circular base, must fit within the square space on the roof. The largest circle that can fit inside a square whose sides measure 8 ft is a circle whose diameter is also 8 ft. This means that the radius of the base of the cylinder is 4 ft. The height of the tank is 14 ft (which is given in the question).

Substitute these measurements into the given equation to find the capacity of the rainwater tank: $V = \pi \times (4\text{ ft})^2 \times 14\text{ ft} = 703.7\text{ ft}^3$.

25. With all of this activity on the roof, the developers have asked the architect to design a rectangular enclosure for the garden. Being eco-friendly, they decide to recycle used shipping palates with chicken wire to create the enclosure. The length and width of the garden are 22 m and 8 m, respectively and there is enough material to enclose a volume of 369.6 m^3. The architect wants to make a virtual model to show the developers, how tall is the enclosure?

a. 2.1 m
b. 2.7 m
c. 3.2 m
d. 3.5 m
e. 3.9 m

Answer: a
Calculate the height of the enclosure using the quantities given in the problem.
V = 369.6 m^3
l = 22 m
w = 8 m
h = ?

Rearrange the equation for the volume of a rectangular solid to solve for the height *h*, which gives $h = \frac{V}{l \times h}$. We can now substitute the values for the variables and solve for *h*: $h = \frac{369.6\text{ m}^3}{22\text{ m} \times 8\text{ m}} = \frac{369.6\text{ m}^3}{176\text{ m}^2} = 2.1\text{ m}$.

26. The architect is making models of the individual residential units in the building. The virtual reality program uses a 1:100 scale. (For example, if a feature is 100 inches long in real life, in the virtual model it will be 1 inch long.) One wall of the unit being modeled will be 9 meters long. What is the length of this wall in pixels in the virtual model?

a. 346.15 pixels
b. 412.66 pixels
c. 520.42 pixels
d. 682.37 pixels
e. 716.29 pixels

Answer: a
Because the virtual model uses a 1:100 scale, divide the real length of the wall by 100 to find out how long it will appear on the computer screen. 9 meters is equivalent to 900 centimeters, so the wall will be $\frac{900\text{ cm}}{100} = 9\text{ cm}$ long on the screen. Using the length of the virtual image of the wall, use the given conversion factor to determine the virtual wall's length in pixels: $9\text{ cm} \times \frac{1\text{ pixel}}{0.026\text{ cm}} = 346.15\text{ pixels}$.

27. The architect makes a three-dimensional drawing of a rectangular unit in the virtual reality program. They lay a three-dimensional grid over the model, which gives a three-dimensional coordinate (*x*, *y*, *z*) to every point in the model. (The *z* coordinate is usually used to denote height.) The line where

one of the walls meets the floor runs from the point (0,0,0) to (9,0,0). The line where the other, shorter wall meets the floor runs from (0,0,0) to (0,6,0). The vertical corner where these two walls meet runs from (0,0,0) to (0,0,3.5). (All measurements are in meters.) What is the total volume of this unit?

a. 141 m^3
b. 158 m^3
c. 174 m^3
d. 189 m^3
e. 203 m^3

Answer: d

To calculate the volume of the rectangular unit determine the length, width, and height of the unit from the coordinates. The first wall goes from (0,0,0) to (9,0,0), so it is 9 meters long. Similarly, the second wall goes from (0,0,0) to (0,6,0), so it is 6 meters long. The line where these two walls meet goes from the floor to the ceiling, or from (0,0,0) to (0,0,3.5), so the unit is 3.5 meters high. Using these values, the total volume: $V = 9\text{ m} \times 6\text{ m} \times 3.5\text{ m} = 189\text{ m}^3$.

28. The developers ask the designer to create a few virtual units that include different furniture and appliance arrangements. The designer starts by placing a (virtual) couch against a wall that runs left to right. The couch is rotated 90°, but this doesn't look right either. The couch is then moved to a corner and rotated an additional 60° (in the same direction as before), which looks much better. What is the total rotation angle in radians of the virtual couch?

a. $\frac{3\pi}{6}$ rad
b. $\frac{3}{6\pi}$ rad
c. $\frac{5\pi}{6}$ rad
d. $\frac{5}{6\pi}$ rad
e. $\frac{7\pi}{6}$ rad

Answer: c

The designer rotates the couch a total of 150°. To calculate the value of this angle in radians, use the conversion relation given in the assumptions, i.e., $360° = 2\pi$ radians. Set up an equation using ratios to solves for the unknown value: $\frac{150°}{360°} = \frac{x\ rad}{2\pi\ rad}$. Multiply both sides by 2π rad and simplify to get $x = \frac{5\pi}{6}$ rad.

29. The architect is able to simulate light in the virtual reality program, which helps to see how the units will look with different window arrangements. Virtual sunlight comes through a floor-to-ceiling window, which is 2.5 m tall. A ray of light coming through the very top of the window hits the floor at an angle of 30°. At what distance from the window does the ray of light hit the floor? (Note: $\tan(30°) = \frac{\sqrt{3}}{3}$.)

a. 4.33 m
b. 4.66 m

c. 5.00 m
d. 5.33 m
e. 5.66 m

Answer: a
The key to this question is knowing that there is a right triangle in the problem. The 30º angle measures where the light touches the floor, so the window is the opposite side, the distance along the floor is the adjacent side, and the path that the light ray takes from the top of the window to the floor is the hypotenuse.
$\mathrm{Tan}(30°) = \frac{\text{opposite}}{\text{adjacent}} = \frac{\sqrt{3}}{3}$, and the tangent of an angle relates the opposite and adjacent sides. The opposite side is 2.5 meters, so substitute these values into the equation to solve for the length of the adjacent side, which can be labeled as *x*: $\frac{2.5\text{ m}}{x} = \frac{\sqrt{3}}{3}; \frac{7.5\text{ m}}{\sqrt{3}} = x = 4.33\text{ m}$.

30. The architect finally has the virtual model of the completed building. The developers want to run a simulation of residents moving through the space. The architect's drafting program places a virtual person at each unit's front door. The virtual person then takes a stroll, first walking east for 4 seconds at a speed of 3 ft/s, then turning north and casually moving at 1.5 ft/s for 12 seconds. What is the total (virtual!) distance that the virtual person has traveled?

a. 28 ft
b. 30 ft
c. 32 ft
d. 34 ft
e. 36 ft

Answer: b
Calculate the distance traveled in both parts of the walk: when the virtual person moves at 3 ft/s and when they move at 1.5 ft/s. Using the formula provided, the distance traveled during the first part is $3\ \frac{\text{ft}}{\text{s}} \times 4\text{ s} = 12\text{ ft}$. The distance traveled during the second part is $1.5\ \frac{\text{ft}}{\text{s}} \times 12\text{ s} = 18\text{ ft}$. Adding these two distances together, the virtual person walked a total distance of 30 ft.

31. The town of Llano, TX has been experiencing a drought. The nearby Llano River usually flows at a rate of 123 cubic feet per second $\left(\frac{\text{ft}^3}{\text{s}}\right)$, but during the drought its flow has been averaging 2.8 $\frac{\text{ft}^3}{\text{s}}$. What is the percentage change in the flow rate of the river during the drought?

a. −42.9%
b. 87.2%
c. 42.9%
d. −97.7%
e. −95.1%

Answer: d

The new value = 2.8 $\frac{\text{ft}^3}{\text{s}}$, and the old value = 123 $\frac{\text{ft}^3}{\text{s}}$.

Using the formula provided, $\frac{2.8-123}{123} \times 100 = \frac{-120.2}{123} \times 100 = -97.7\%$. The correct answer is d.

32. Despite the drought, the Llano River still delivers water to the town's water treatment plant. If the river is flowing at a rate of 2.8 cubic feet per second $\left(\frac{\text{ft}^3}{\text{s}}\right)$, how many gallons of water does it deliver in 1 hour?

a. 67,320.5 gallons
b. 75,398.4 gallons
c. 80,784.0 gallons
d. 86,169.6 gallons
e. 94,248.3 gallons

Answer: b

The flow rate is given in cubic feet per second, so to find the flow rate per hour we use $2.8\frac{\text{ft}^3}{\text{s}} \times \frac{60\ \text{s}}{\text{min}} \times \frac{60\,\text{min}}{\text{h}} = 10{,}080\frac{\text{ft}^3}{\text{h}}$. Then, to find the volume of water delivered in gallons in one hour, multiply this answer by the conversion rate, $10{,}080\frac{\text{ft}^3}{\text{h}} \times 7.48\frac{\text{gal}}{\text{ft}^3} \times 1\ \text{h} = 75{,}398.4$ gallons. The correct answer is b.

33. During times of drought, an electric pump is used 24 hours a day to draw water from various wells servicing Agua Fria to provide the town of Llano with enough water for its daily needs. The pump requires 18 kW of power to run, and the electric rate in Llano is $0.14/kWh. How much does it cost Agua Fria to use the pump if the drought lasts for 30 days?

a. $1,432.60
b. $1,519.30
c. $1,592.90
d. $1,655.40
e. $1,814.40

Answer: e
First, find the number of kWh used per day: 18 kW x 24 hours = 432 kWh/day.
Then, we find the cost per day to run the pump: 432 kWh/day x $0.14/kWh = $60.48/day.
Finally, find the cost to run the pump for the entire month: $60.48/day x 30 days = $1,814.40. The correct answer is e.

34. When Agua Fria uses the electric water pump during droughts it incurs an additional cost of $36,000/year. In order for the company to break even (revenues equal costs), it must charge households extra for the use of this well water. If there are 450 households in the town of Llano, what should Agua Fria charge each household per month?

a. $6.67
b. $15.01
c. $40.02
d. $53.36
e. $80.00

Answer: a
First, find what each household should be charged for the year for Agua Fria to break even:
$36,000/year ÷ 450 households = $80/household each year.
Then, we can find how much each household will be charged per month: $80/year ÷ 12 months/year = $6.67/month. The correct answer is a.

35. The water that Agua Fria pumps from its wells is stored in a large concrete container in the shape of a cylinder. The radius of the container is 8 meters and it is 14 meters tall. What is the maximum volume of water that this container can hold?

a. 351.86 m^3
b. 1,105.40 m^3
c. 1,452.67 m^3
d. 2,814.87 m^3
e. 4,926.02 m^3

Answer: d

Using the given equation, with r = 8 m and h = 14 m, we find that the volume of the container is $V = p´\ 8^2\ ´\ 14 = p´\ 64´\ 14 = 2{,}814.87$ m³. This is the maximum amount of water that the container can hold. The correct answer is d.

36. Because the water that Agua Fria draws from its wells is rather brackish (salty), a desalination system is used to remove the salt and produce fresh water. In the town of Llano, the well water has a salt concentration of 17 g/L. If the desalination system can process 5,000 gallons of water/day, how many kilograms (kg) of salt will be removed each day?

a. 85.00 kg
b. 322.15 kg
c. 850.00 kg
d. 3221.50 kg
e. 8500.50 kg

Answer: b
First, calculate the number of liters of water the desalination system processes every day: 5,000 gal/day x 3.79 L/gal = 18,950 L/day.
Then, calculate the mass of salt that will be produced each day: 18,950 L/day x 17 g/L = 322,150 g/day.
Finally, divide by 1,000 to find the number of kilograms of salt produced every day: 322,150 g/day x 1 kg/1,000 g = 322.15 kg/day.

37. During times of drought, limits are set on the amount of water that should be used for lawn and garden care every week. Residents are asked to use only 0.25 ft^3 of water for every square foot of lawn. If the average house has a lawn size of 0.55 acres, how many cubic feet of water can be used for lawn and garden care every week?

a. 4,526.3 ft^3
b. 5,256.6 ft^3
c. 5,989.5 ft^3
d. 6,289.1 ft^3
e. 6,812.8 ft^3

Answer: c
First, find the size of an average lawn in square feet: 0.55 acres x 43,560 ft^2/acre = 23,958 ft^2.
Then, find out how much water can be used on a lawn of this size: 23,958 ft^2 x 0.25 ft^3 water/ft^2 lawn = 5,989.5 ft^3 water. The correct answer is c.

38. To avoid problems with future local droughts, Agua Fria may become part of a regional water-sharing system. This system would—when needed—bring water from neighboring areas through a pipe with a diameter of 60 in. at a flow rate of 36 ft^3/s. At what velocity will this water be delivered through the pipe?

a. 0.46 ft/s
b. 0.55 ft/s
c. 1.83 ft/s

d. 2.29 ft/s
e. 2.71 ft/s

Answer: c
First, find the area of the pipe in ft.^{2}. The diameter is 60 in.and the radius of the pipe is 30 in., or 2.5 ft. The area of the pipe is $(2.5 \text{ ft})^2 \times \pi = 19.64 \text{ ft}^2$. Then, calculate the velocity of the water by dividing the flow rate by this area: $v = 36 \text{ ft}^3\text{/s.} \div 19.64 \text{ ft}^2 = 1.83$ ft./s. The correct answer is c.

39. During droughts, Agua Fria can either receive water through the regional water sharing system at a cost of $240/4,800 gallons, or pump and desalinate water from its own wells at a cost of $100/2,500 gallons. What is the difference in cost per gallon between these two methods?

a. $0.01
b. $0.02
c. $0.03
d. $0.04
e. $0.05

Answer: a
First, calculate the cost per gallon of each method:
- Water-sharing: $240/4,800 gallons = $0.05/gallon.
- Well: $100/2,500 gallons = $0.04/gallon.
Then we can see that the difference between the costs of these two methods is $0.05/gallon − $0.04/gallon = $0.01/gallon. The correct answer is a.

40. Although Agua Fria can currently choose between the regional water-sharing system and its own wells, the aquifer that supplies its wells is disappearing. The aquifer currently has a volume of 1,550,000 gallons, and Agua Fria pumps 123,000 gallons/year from its wells. At this rate, and assuming that the aquifer is not replenished, how long will it be until Agua Fria is completely dependent on the regional water-sharing system for emergencies?

a. 8.3 years
b. 9.1 years
c. 10.8 years
d. 11.6 years
e. 12.6 years

Answer: e
Calculate the number of years that the aquifer can still provide its own water: 1,550,000 gallons ÷ 123,000 gallons/year = 12.6 years. The correct answer is e.