SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are several passages in this test. Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

You are NOT permitted to use a calculator on this test.

Passage I

Jumping spiders prey on many types of small insects. Researchers predicted that the jumping spider *Habronattus pyrrithrix* would prefer prey of some colors over prey of other colors. Three experiments were conducted to test this prediction.

Experiment 1

Small crickets (*Acheta domesticus*) were dyed either red, yellow, green, blue, or brown when they drank water containing a dye. Two crickets of each color were placed in the same box. Then, an *H. pyrrithrix* jumping spider that had been recently captured from the wild (wild-caught) was placed in the center of the box, and the color of each cricket eaten by the spider during 1 hr was recorded. Each time a cricket was eaten, an additional cricket of the same color was added to the box. This procedure was repeated with 99 additional wild-caught *H. pyrrithrix* jumping spiders. The average number of crickets of each color eaten in 1 hr is shown in Figure 1.

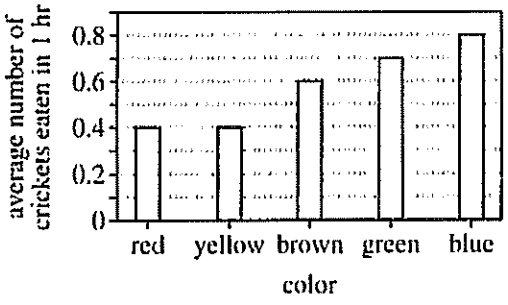


Figure 1

Experiment 2

Experiment 1 was repeated using the same set of 100 wild-caught jumping spiders, which had been kept in cages in the laboratory for 4 weeks. The average number of crickets of each color eaten in 1 hr is shown in Figure 2.

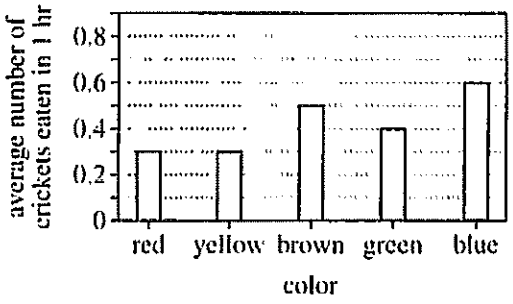


Figure 2

Experiment 3

Experiment 1 was repeated except with 100 laboratory-raised *H. pyrrithrix* jumping spiders that had spent their entire lives in cages in the laboratory. The average number of crickets of each color eaten in 1 hr is shown in Figure 3.

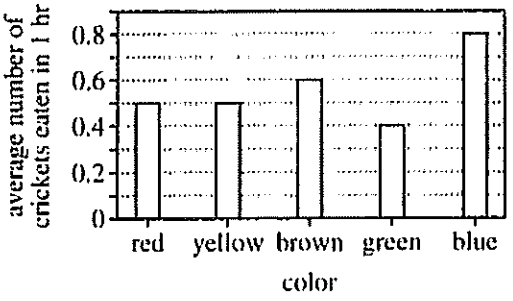


Figure 3

Figures adapted from Lisa A. Taylor et al., "Colour Use by Tiny Predators: Jumping Spiders Show Colour Biases During Foraging." ©2014 by The Association for the Study of Animal Behaviour.

1. Suppose that in a new experiment the researchers repeated Experiment 3 except that they recorded the color of each cricket eaten by a spider during 2 hr. Assuming that the spiders ate crickets for the entire 2 hr, would the total number of crickets eaten by the spiders more likely have been less than or greater than the total number of crickets eaten in Experiment 3 ?

   A. Less, because the amount of time the spiders spent eating crickets would have been one-third as great.
   B. Less, because the amount of time the spiders spent eating crickets would have been one-half as great.
   C. Greater, because the amount of time the spiders spent eating crickets would have been two times as great.
   D. Greater, because the amount of time the spiders spent eating crickets would have been three times as great.

2. Were the results of the experiments consistent with the researchers' prediction?

   F. Yes; in each experiment, on average, the spiders ate the same number of crickets of each color in 1 hr.
   G. Yes; in each experiment, on average, the spiders ate more blue crickets than crickets of any other given color in 1 hr.
   H. No; in each experiment, on average, the spiders ate the same number of crickets of each color in 1 hr.
   J. No; in each experiment, on average, the spiders ate more blue crickets than crickets of any other given color in 1 hr.

3. What was the total number of spiders needed to conduct Experiments 1–3 ?

   A. 100
   B. 200
   C. 300
   D. 400

4. A student wanted to determine if the results for wild-caught spiders tested shortly after they were captured would be the same for different species of prey. Which of the following experiments should the student conduct?

   F. Repeat Experiment 1 with *A. domesticus* as the species of prey.
   G. Repeat Experiment 3 with *A. domesticus* as the species of prey.
   H. Repeat Experiment 1 with a species of prey other than *A. domesticus*.
   J. Repeat Experiment 3 with a species of prey other than *A. domesticus*.

5. Each of the values plotted in Figure 1 was most likely calculated using which of the following expressions?

   A. $\dfrac{\text{Total number of crickets that were eaten by laboratory-raised spiders}}{\text{Number of laboratory-raised spiders}}$

   B. $\dfrac{\text{Total number of crickets that were eaten by wild-caught spiders}}{\text{Number of wild-caught spiders}}$

   C. $\dfrac{\text{Number of crickets of a particular color that were eaten by laboratory-raised spiders}}{\text{Number of laboratory-raised spiders}}$

   D. $\dfrac{\text{Number of crickets of a particular color that were eaten by wild-caught spiders}}{\text{Number of wild-caught spiders}}$

6. Which, if either, of the statements given below about the spiders tested in the experiments is(are) consistent with the information in the passage?

   I. All the spiders belonged to the same genus.
   II. All the spiders belonged to the same species.

   F. I only
   G. II only
   H. Both I and II
   J. Neither I nor II

7. Which of the following statements is best supported by the results of Experiments 1 and 2 ? After the wild-caught spiders had been kept in cages for 4 weeks, they ate, on average:

   A. more green crickets in 1 hr than did the laboratory-raised spiders.
   B. fewer green crickets in 1 hr than did the laboratory-raised spiders.
   C. more crickets in 1 hr than they did when they had recently been captured from the wild.
   D. fewer crickets in 1 hr than they did when they had recently been captured from the wild.

Passage II

The Indian beech tree (*Millettia pinnata*) produces oil-rich seeds. The oil is inedible; however, it can be converted to *biodiesel fuel* in a chemical reaction with methanol (a solvent) and a catalyst. Scientists studied the production of biodiesel fuel from *M. pinnata* oil.

Experiment

In each trial, the following steps were performed:

1. Twenty mL of *M. pinnata* oil was mixed with 80 mL of methanol in a flask to form a solution.
2. A particular mass of a catalyst—either sodium hydroxide (NaOH) or potassium hydroxide (KOH)—was dissolved in the flask.
3. The flask was fitted with a temperature probe, sealed, placed in a microwave oven, and then microwaved until the contents reached 60°C.
4. The flask was maintained at 60°C in the microwave for a particular amount of time (the *microwave time*).
5. The flask was immersed in an ice water bath.
6. The amount of biodiesel fuel produced was measured, and the percentage of the *M. pinnata* oil that had been converted to biodiesel fuel was calculated.

For any given combination of conditions (identity of catalyst, concentration of catalyst, and microwave time), 4 trials were conducted. The table shows, for each set of trials, the experimental conditions and the average percent of the oil that was converted to biodiesel fuel.

Set of trials	Catalyst	Catalyst concentration (percent by mass)	Microwave time (min)	Average percent of *M. pinnata* oil converted to biodiesel fuel
1–4	NaOH	0.5	5	95.0
5–8	NaOH	1.0	5	91.2
9–12	NaOH	1.5	5	N.D.*
13–16	KOH	0.5	5	89.2
17–20	KOH	1.0	5	96.0
21–24	KOH	1.5	5	95.0
25–28	NaOH	1.0	3	93.2
29–32	NaOH	1.0	7	96.4
33–36	KOH	1.0	3	88.6
37–40	KOH	1.0	7	96.5
41–44	KOH	1.0	10	97.3

*N.D.—Not determined.

Table adapted from M. L. Savaliya and B. Z. Dholakiya, "Chemical Transformation of Triglycerides of Fatty Acid of *Pongamia pinnata* Seed to Fatty Acid Methyl Esters by Microwave Irradiation." ©2013 by M. L. Savaliya and B. Z. Dholakiya.

8. Which step was most likely performed to stop the reaction that was occurring in the flask?

   F. Step 3
   G. Step 4
   H. Step 5
   J. Step 6

9. According to the table, which of the following combinations of catalyst, catalyst concentration, and microwave time resulted in the *lowest* average percent of *M. pinnata* oil being converted to biodiesel fuel?

	catalyst	catalyst concentration	microwave time
A.	NaOH	1.0%	3 min
B.	NaOH	1.0%	7 min
C.	KOH	1.0%	7 min
D.	KOH	1.5%	5 min

10. Consider the results for each combination of catalyst concentration and microwave time that was tested. Compared with the average percent of *M. pinnata* oil converted to biodiesel fuel in the NaOH trials, the average percent of *M. pinnata* oil converted to biodiesel fuel in the KOH trials was:

    F. always higher.
    G. always lower.
    H. always the same.
    J. sometimes higher and sometimes lower.

11. Which of the following expressions gives the volume of methanol used in the experiment?

    A. $\frac{80 \text{ mL methanol}}{\text{trial}} \times 11 \text{ trials}$

    B. $\frac{80 \text{ mL methanol}}{\text{trial}} \times 44 \text{ trials}$

    C. $\frac{100 \text{ mL methanol}}{\text{trial}} \times 11 \text{ trials}$

    D. $\frac{100 \text{ mL methanol}}{\text{trial}} \times 44 \text{ trials}$

12. The average percent of *M. pinnata* oil converted to biodiesel fuel in Trials 25–28 differed from that in Trials 33–36 because the 2 sets of trials differed with respect to the:

    F. identity of the catalyst.
    G. concentration of the catalyst.
    H. microwave time.
    J. temperature at which the flask was maintained.

13. For the trials conducted with 1.0% KOH by mass, as the microwave time increased, the average percent of *M. pinnata* oil converted to biodiesel fuel:

    A. increased only.
    B. decreased only.
    C. increased and then decreased.
    D. decreased and then increased.

14. The solution formed in Step 1 of each trial had a mass of 82 g. Based on this information and the table, the mass of the catalyst added to the flask in Step 2 of Trial 5 was closest to which of the following?

    F. 0.4 g
    G. 0.8 g
    H. 4 g
    J. 8 g

Passage III

Heating degree-days (HDD) and *cooling degree-days* (CDD) are used to estimate the amount of energy needed to heat or cool, respectively, any building on a given day. HDD are calculated by subtracting the daily mean temperature (T_d) from a base temperature of 65°F. Each degree difference is one HDD. CDD are calculated by subtracting 65°F from T_d.

Table 1

City	Latitude	Annual total: HDD	Annual total: CDD
Miami, FL	25°47′ N	114	4,625
Dallas, TX	32°47′ N	452	4,740
Los Angeles, CA	34°03′ N	1,400	680
Denver, CO	39°44′ N	6,596	1,110
New York, NY	40°40′ N	4,965	1,076
Chicago, IL	41°53′ N	6,684	1,043
Boston, MA	42°21′ N	5,726	917
Minneapolis, MN	44°59′ N	8,195	1,077
Seattle, WA	47°37′ N	2,630	3,033
Anchorage, AK	61°31′ N	9,726	88

Note: HDD = 65°F − T_d for all T_d < 65°F; CDD = T_d − 65°F for all T_d > 65°F

Table 1 lists, for each of 10 US cities, the latitude of the city and the city's total HDD and CDD for a 1 yr period.

For the state of Illinois, the annual total HDD and the annual total CDD were determined for each of the years 1985–2010 (see Figure 1).

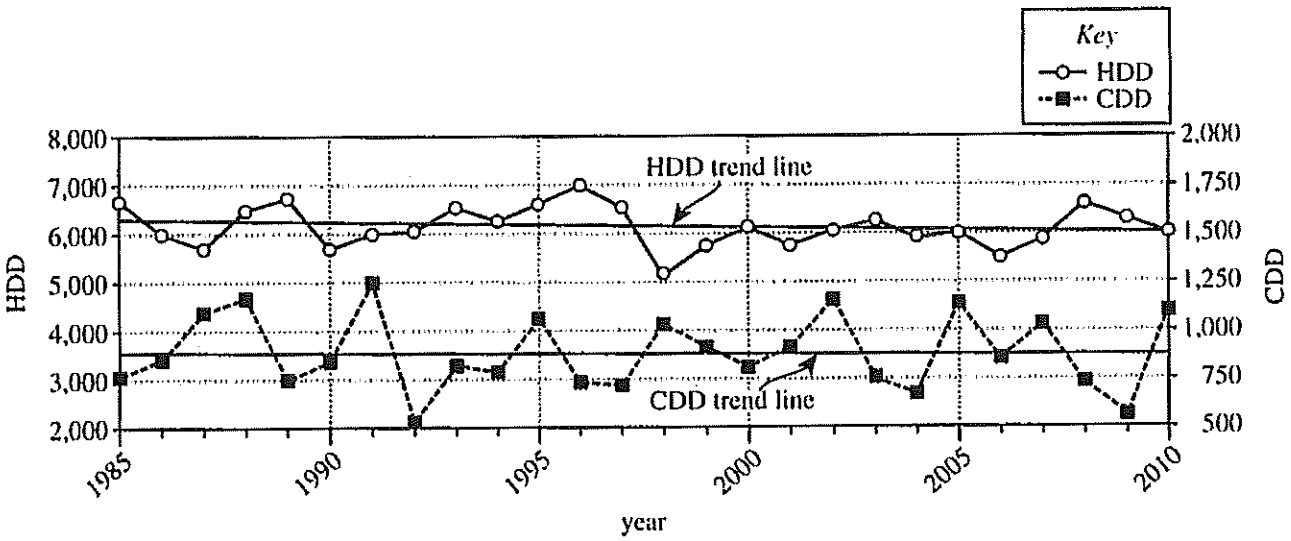


Figure 1

15. According to Figure 1, did the maximum HDD occur during the same year as the minimum CDD ?

A. Yes; the maximum HDD and the minimum CDD both occurred in 1992.
B. Yes; the maximum HDD and the minimum CDD both occurred in 1996.
C. No; the maximum HDD occurred in 1992, whereas the minimum CDD occurred in 1996.
D. No; the maximum HDD occurred in 1996, whereas the minimum CDD occurred in 1992.

16. Based on Table 1, in Dallas, the total CDD was approximately how many times as great as the total HDD ?

F. $\frac{1}{10}$
G. $\frac{1}{5}$
H. 5
J. 10

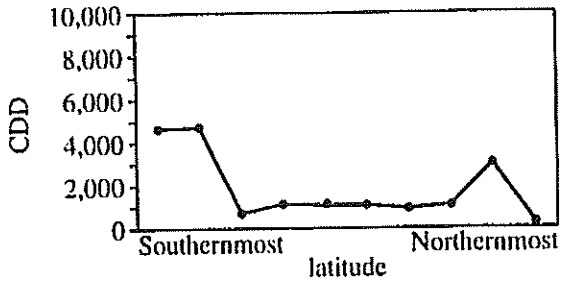
17. Based on Table 1, for all the cities between 40°N and 50°N latitude, which of the following statements describing HDD or CDD is accurate? In a 1 yr period, the total:

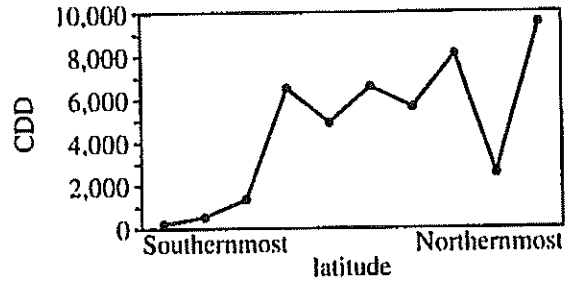
A. HDD was always greater than 2,500.
B. HDD was always greater than the total CDD.
C. CDD was always greater than 1,000.
D. CDD was always greater than the total HDD.

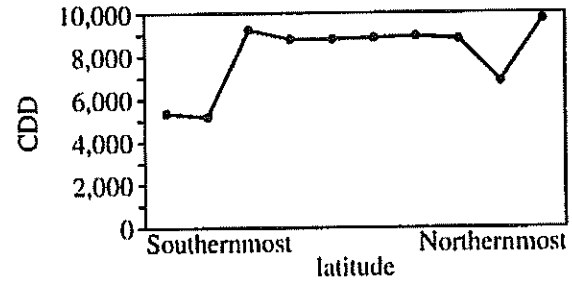
18. Assume that on a particular day, $T_d = 65°F$. For this day, what HDD value would be calculated and what CDD value would be calculated?

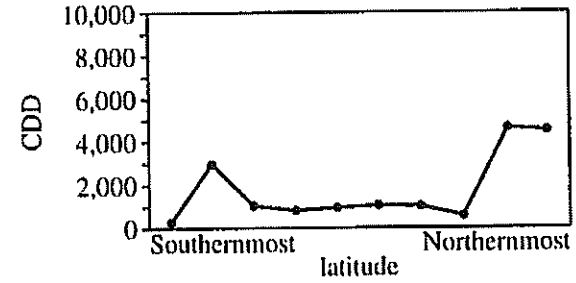
	HDD	CDD
F.	0	0
G.	0	5
H.	5	0
J.	5	5

19. Which of the following graphs best illustrates the latitude and the CDD for each of the cities listed in Table 1 ?

A.


B.


C.


D.


20. Consider the HDD equation and the HDD trend line shown in Figure 1. The slope of that trend line is negative, which indicates that, over the 26 yr period, the average value of T_d:

F. decreased only.
G. increased only.
H. remained constant.
J. decreased and then increased.

Passage IV

The amoeba *Entamoeba histolytica* can infect the human digestive tract. Scientists conducted 2 experiments to study the *amoebicidal* (amoeba-killing) activity of human milk.

Experiment 1

Ten milliliters of a mixture of *nutrient medium* (NM) and *saline solution* (SS) that was 5% SS by volume was put in a test tube. This procedure was performed twice more, except that the percents by volume of SS were 10% and 15%, respectively. Ten milliliters of only NM was put in a fourth test tube. Next, 1×10^7 *E. histolytica* were added to each test tube. Then, a second set of test tubes was likewise prepared, except that human milk was substituted for SS. All 8 test tubes were incubated at 37°C for 1 hr. At the end of incubation, the *percent survival* (percent of the added *E. histolytica* that were still alive) was determined for each test tube (see Figure 1).

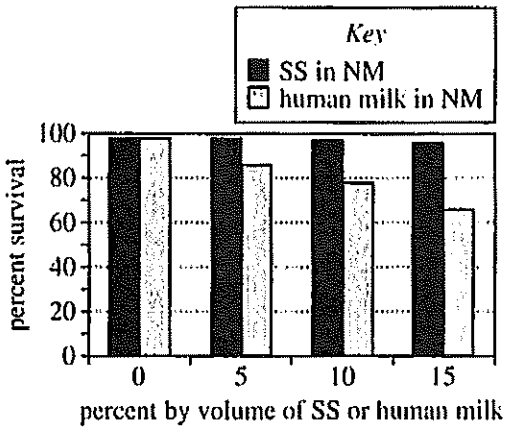


Figure 1

Experiment 2

A sample of human milk was separated into 3 fractions: *casein* (a protein), lipids, and noncasein proteins. Ten milliliters of a mixture of NM and SS that was 10% SS by volume was put in a test tube. This procedure was repeated 3 times, except that each time a different human milk fraction was substituted for SS. Next, 1×10^7 *E. histolytica* were added to each of the test tubes. Then, 2 more sets of 4 test tubes were likewise prepared. Each set of test tubes was incubated at 37°C for a different period of time: 3 hr, 6 hr, or 9 hr. At the end of incubation, the percent survival was determined for each test tube (see Figure 2).

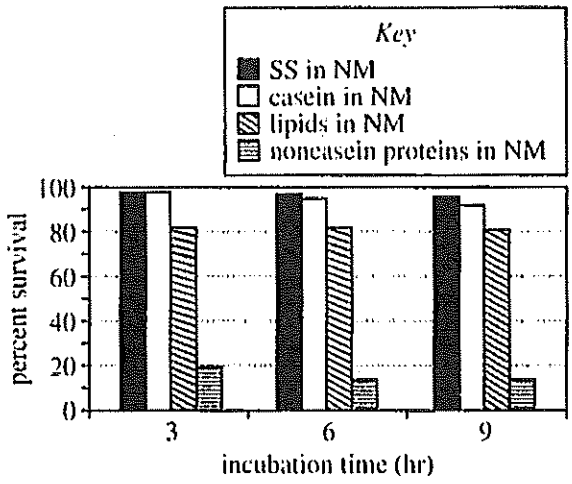


Figure 2

Figures adapted from Nidia León-Sicairos et al., "Amoebicidal Activity of Milk, Apo-lactoferrin, sIgA and Lysozyme." ©2006 by Marshfield Clinic.

21. In Experiment 2, at each incubation time, which NM mixture resulted in the *fewest* surviving *E. histolytica*?

A. SS in NM
B. Casein in NM
C. Lipids in NM
D. Noncasein proteins in NM

22. In Experiment 2, for which of the incubation times did the scientists include a control to determine whether a substantial decrease in *E. histolytica* survival occurred in the absence of a human milk fraction?

F. 3 hr only
G. 6 hr only
H. 9 hr only
J. All 3 incubation times

23. Suppose that an incubation time of 12 hr had been tested in Experiment 2. The percent survival of the *E. histolytica* in the test tube containing lipids in NM would most likely have been closest to which of the following values?

A. 15%
B. 20%
C. 80%
D. 95%

24. Which of the following questions were the scientists most likely attempting to answer in Experiment 1 ?

F. Is the percent survival of *E. histolytica* exposed to SS and *E. histolytica* exposed to human milk affected by increasing incubation time from 1 hr to 3 hr ?
G. Is the percent survival of *E. histolytica* exposed to SS and *E. histolytica* exposed to lipids affected by increasing incubation time from 1 hr to 3 hr ?
H. Does the percent survival for *E. histolytica* exposed to the casein fraction differ from the percent survival for *E. histolytica* exposed to the lipids fraction?
J. Does the percent survival for *E. histolytica* exposed to human milk differ from the percent survival for *E. histolytica* exposed to SS ?

25. In Experiment 1, the dye *trypan blue* was added to each test tube at the end of incubation. Dead *E. histolytica* are stained by trypan blue; living *E. histolytica* are NOT stained by trypan blue. Approximately what percent of the *E. histolytica* in the test tube containing 10% human milk in NM were stained by the trypan blue?

A. 10%
B. 20%
C. 80%
D. 100%

26. To best compare the amoebicidal activity of each of the 3 human milk fractions tested in Experiment 2 to the amoebicidal activity of human milk that has not been separated into fractions, the scientists should repeat the procedures of:

F. Experiment 1, except include a test tube containing a mixture of NM and noncasein proteins in each set of test tubes.
G. Experiment 1, except include a test tube containing a mixture of NM and human milk in each set of test tubes.
H. Experiment 2, except include a test tube containing a mixture of NM and noncasein proteins in each set of test tubes.
J. Experiment 2, except include a test tube containing a mixture of NM and human milk in each set of test tubes.

27. An *E. histolytica* possesses which of the following pairs of characteristics?

A. Has a nucleus; is unicellular
B. Has a nucleus; is multicellular
C. Does not have a nucleus; is unicellular
D. Does not have a nucleus; is multicellular

Passage V

For a demonstration on electric current, a teacher mounted 2 identical copper cables vertically and connected the cables to switch boxes as shown in Figure 1.

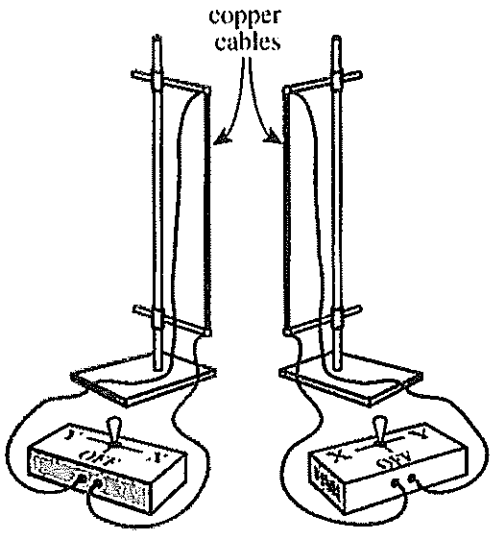


Figure 1

Each switch had 3 positions: X, Y, and OFF. The teacher flipped both switches from the OFF position to Position X, and the cables bent toward each other. Then, she flipped one switch to Position Y, and the cables bent away from each other. Finally, she flipped the other switch to Position Y, and the cables bent toward each other. See Figure 2.

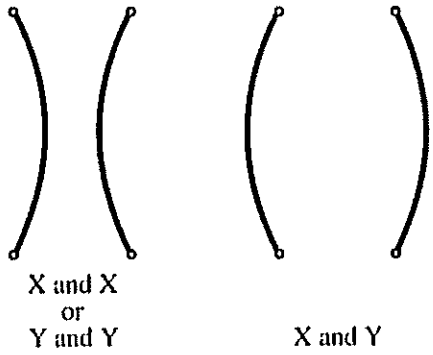


Figure 2

The teacher asked each of 3 students to explain these observations.

Student 1

The switches controlled the direction of current flow through the cables: upward in Position X and downward in Position Y.

Each current generated an electric field. Because each current consisted of positive charges, its field pointed in the direction of current flow. Electric fields attract each other when parallel and repel each other when *antiparallel* (pointing in opposite directions). The field generated by one current attracted or repelled the field generated by the other current.

Student 2

The switches controlled the direction of current flow as Student 1 described; however, the currents consisted of negative charges.

Each current generated a magnetic field. A magnetic field exerts a force on any charge in motion, and this force is always perpendicular to the direction of the charge's motion. When the currents were parallel, the field generated by one current attracted the charges in the other current. When the currents were antiparallel, the field generated by one current repelled the charges in the other current.

Student 3

The switches controlled the signs of charges in the currents: positive in Position X and negative in Position Y.

Regardless of whether they are at rest or in motion, charges of like sign attract each other and charges of opposite signs repel each other. The charges in one current attracted or repelled the charges in the other current.

28. Each of the following statements was either claimed or implied by Student 3. Which is scientifically *inaccurate*?

F. Charges of like sign attract each other.
G. Charges can be at rest.
H. A current consists of charges in motion.
J. There are 2 possible signs for electric charge: positive and negative.

29. Assume that the currents in the demonstration consisted of a single type of charged particle. If Student 2's explanation is correct, these particles were most likely:

A. protons.
B. electrons.
C. neutrons.
D. photons.

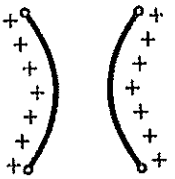
30. If Student 2's explanation is correct, then a magnetic field would be expected to exert a force on which of the following objects?

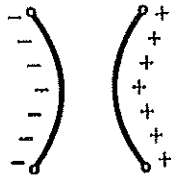
F. An ion in motion
G. An ion at rest
H. A neutral atom in motion
J. A neutral atom at rest

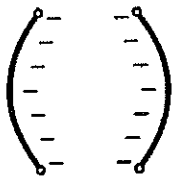
31. Based on Student 1's explanation, when the switch on the left was in Position X and the switch on the right was in Position Y, were the electric fields generated by the currents parallel or antiparallel?

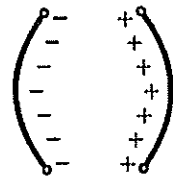
A. Parallel, because the currents were both flowing upward.
B. Parallel, because the currents were both flowing downward.
C. Antiparallel, because the left-hand current was flowing upward and the right-hand current was flowing downward.
D. Antiparallel, because the left-hand current was flowing downward and the right-hand current was flowing upward.

32. Which of the following figures is consistent with both Figure 2 and Student 3's explanation?

F. 
X and X

H. 
X and Y

G. 
X and Y

J. 
Y and Y

33. In regard to attractive and repulsive interactions, how does Student 1's explanation differ from Student 2's explanation? Student 1 claimed that:

A. a field attracts or repels another field, whereas Student 2 claimed that a field attracts or repels charges.
B. a field attracts or repels charges, whereas Student 2 claimed that a field attracts or repels another field.
C. charges attract or repel fields, whereas Student 2 claimed that charges attract or repel other charges.
D. charges attract or repel other charges, whereas Student 2 claimed that charges attract or repel fields.

34. Which of the following procedures would best test Student 2's explanation? With current flowing through 1 of the cables, determine if:

F. a positively charged plastic rod, when held at rest near the cable, attracts or repels the cable.
G. a compass needle is deflected when brought near the cable.
H. an uncharged rubber strip, when held at rest near the cable, bends toward or away from the cable.
J. a lightbulb is illuminated when connected to the cable.

Passage VI

Figure 1 shows how the *H_2O vapor pressure* (the pressure exerted by the H_2O vapor in air) varies with the relative humidity (*RH*) of the air at CTP, which denotes a constant temperature of 25°C and pressure of 101,325 pascals (Pa). Figure 2 shows how air density varies with H_2O vapor pressure at CTP.

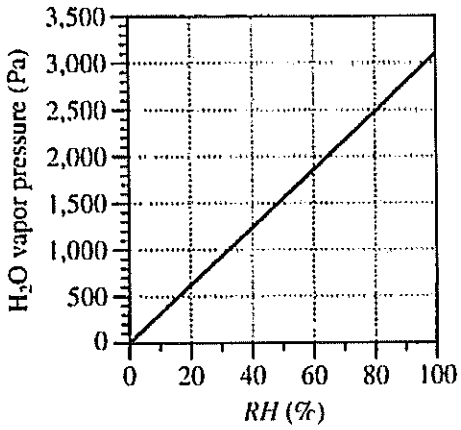


Figure 1

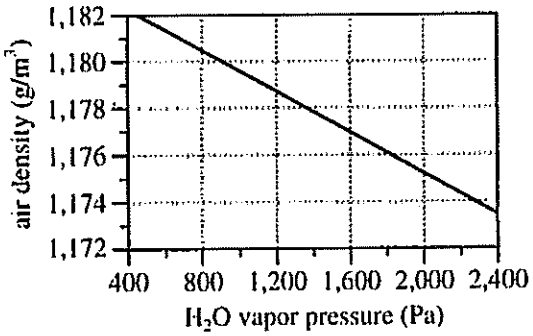


Figure 2

At CTP, the air above an aqueous solution in a closed container has a constant *RH*. Figure 3 shows, for 3 compounds, how the *RH* of the air at CTP in a closed container varies with the percent by mass of the compound dissolved in the aqueous solution in the container.

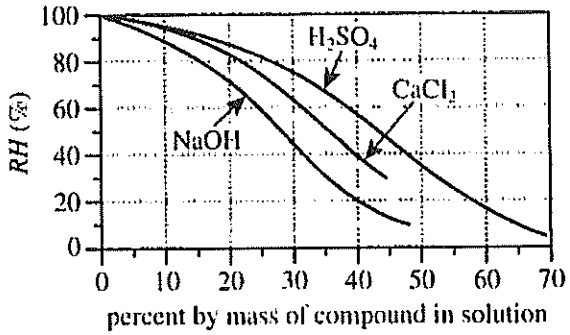


Figure 3

Figure 3 adapted from James G. Speight, *Lange's Handbook of Chemistry*, 16th ed. ©2005 by McGraw-Hill, Inc.

35. Based on Figures 1 and 2, as *RH* increases from 20% to 80% at CTP, air density:

    A. decreases only.
    B. increases only.
    C. decreases, then increases.
    D. increases, then decreases.

36. Based on Figure 2, air at CTP that has a density of 1,172 g/m^3 will have an H_2O vapor pressure closest to which of the following?

    F. 2,400 Pa
    G. 2,700 Pa
    H. 3,000 Pa
    J. 3,300 Pa

37. According to Figure 3, at CTP, if pure H_2O is kept in a closed container, the *RH* of the air in the container will be:

A. 0%.
B. 40%.
C. 80%.
D. 100%.

38. Based on Figure 2, will a 1 L sample of air at CTP have a greater mass if it has an H_2O vapor pressure of 1,000 Pa or if it has an H_2O vapor pressure of 2,000 Pa ?

F. 1,000 Pa, because it will be less dense.
G. 1,000 Pa, because it will be more dense.
H. 2,000 Pa, because it will be less dense.
J. 2,000 Pa, because it will be more dense.

39. Consider a 35% by mass aqueous solution of H_2SO_4 in a closed container. Based on Figures 1–3, if the air above the solution in the container is at CTP, the density of the air will be closest to which of the following?

A. 1,172 g/m^3
B. 1,175 g/m^3
C. 1,178 g/m^3
D. 1,181 g/m^3

40. Consider two 20% by mass aqueous solutions, one of NaOH and one of H_2SO_4, each in a separate, closed container. A student claimed that the H_2O vapor pressure at CTP will be greater in the air above the H_2SO_4 solution than it will be in the air above the NaOH solution. Do Figures 1 and 3 support this claim?

F. No, because a higher *RH* results from the NaOH solution.
G. No, because a higher *RH* results from the H_2SO_4 solution.
H. Yes, because a higher *RH* results from the NaOH solution.
J. Yes, because a higher *RH* results from the H_2SO_4 solution.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.