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

A study was conducted to examine whether female *Blattella germanica* (a species of cockroach) prefer to eat cat food, cheese, ham, or peanuts. First, 200 mg of each of the 4 foods was separately placed into a single box. Then, adult female *B. germanica* were added to the box. Figure 1 shows how the mass, in mg, of each food in the box changed over time after the addition of the *B. germanica*. Table 1 shows the percent by mass of carbohydrates, lipids, proteins, and water, respectively, present in each of the 4 foods tested in the study.

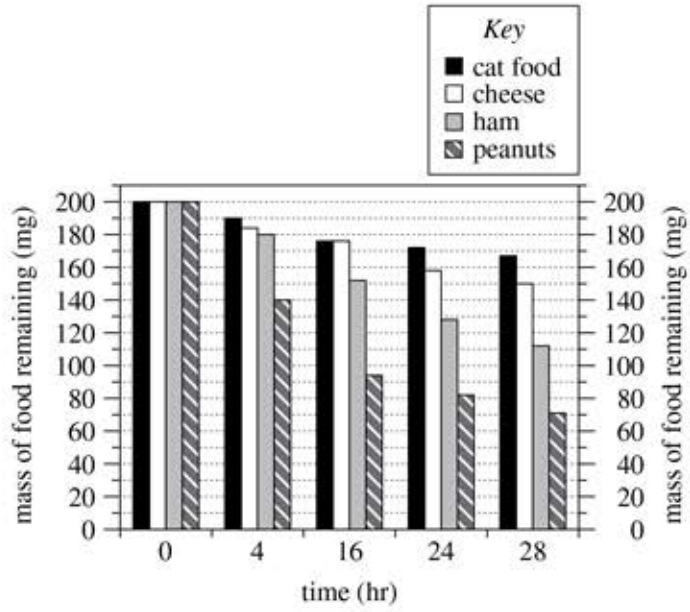


Figure 1

Figure adapted from Prachumporn Lauprasert et al., "Food Preference and Feeding Behavior of the German Cockroach, *Blattella germanica* (Linnaeus)." ©2006 by the Faculty of Science, Chulalongkorn University.

Table 1

Food	Percent by mass			
	carbohydrates	lipids	proteins	water
Cat food	1.2	6.0	16.9	66.2
Cheese	0.5	27.7	20.8	48.4
Ham	0.0	18.2	23.6	57.1
Peanuts	15.8	49.6	26.2	6.4

Table adapted from U.S. Department of Agriculture, *USDA National Nutrient Database for Standard Reference, Release 24*. 2011.

1. According to Figure 1, the mass of cheese remaining at 4 hr was closest to which of the following values?

A. 140 mg
B. 176 mg
C. 185 mg
D. 190 mg

2. Suppose a company wants to use food as bait in a trap designed to capture female *B. germanica*. Based on Figure 1, which of the 4 foods should the company place in the trap to maximize the chance of capturing female *B. germanica*?

F. Cat food
G. Cheese
H. Ham
J. Peanuts

3. Consider the 4 foods in order of the percent by mass of proteins, from lowest to highest. From food to food, as the percent by mass of proteins increased, the mass of food remaining at 28 hr:

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

4. Consider the statement "The *B. germanica* ate the food between 0 hr and 4 hr, between 4 hr and 16 hr, between 16 hr and 24 hr, and between 24 hr and 28 hr." This statement is consistent with the data in Figure 1 for how many of the 4 foods?

   F. 1
   G. 2
   H. 3
   J. 4

5. A student predicted that the *B. germanica* would eat less cat food than ham by the end of the study. Do the data in Figure 1 support this prediction?

   A. Yes; at 28 hr, the mass of cat food remaining was about 55 mg greater than the mass of ham remaining.
   B. Yes; at 28 hr, the mass of cat food remaining was about 95 mg greater than the mass of ham remaining.
   C. No; at 28 hr, the mass of cat food remaining was about 55 mg less than the mass of ham remaining.
   D. No; at 28 hr, the mass of cat food remaining was about 95 mg less than the mass of ham remaining.

6. Based on Table 1, when 200 mg of each of the 4 foods was placed in the box, water accounted for more than 100 mg of the mass of which food(s)?

   F. Peanuts only
   G. Cat food and ham only
   H. Cheese and peanuts only
   J. Cat food, cheese, and ham only

Passage II

A teacher provided the table below to the students in a science class. The table gives 5 properties for each of Samples A–H. The students were told to assume that each sample is a completely solid cube composed of a single hypothetical pure substance.

Sample	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)
A	8.0	4.0	2.0	126	747
B	8.0	4.0	2.0	342	959
C	6.0	3.0	2.0	237	885
D	6.0	3.0	2.0	237	885
E	8.0	2.0	4.0	126	747
F	8.0	2.0	4.0	126	747
G	4.0	1.0	4.0	126	747
H	4.0	1.0	4.0	342	959

Note: Assume that mass, volume, and density were determined at 20°C and that all 5 properties were determined at 1 atmosphere (atm) of pressure.

The teacher asked each of 4 students to explain how these data could be used to predict which samples are composed of the same substance.

Student 1

If 2 samples have the same values for all 5 properties, they are composed of the same substance. If 2 samples have different values for any of the 5 properties, they are composed of different substances.

Student 2

If 2 samples have the same values for any 3 or more of the 5 properties, they are composed of the same substance. If 2 samples have the same values for fewer than 3 of the 5 properties, they are composed of different substances.

Student 3

If 2 samples have the same mass, volume, and density, they are composed of the same substance. If 2 samples have different values for any of these 3 properties, they are composed of different substances. Neither melting point nor boiling point, by itself, can distinguish between substances.

Student 4

If 2 samples have the same density, melting point, and boiling point, they are composed of the same substance. If 2 samples have different values for any of these 3 properties, they are composed of different substances. Neither mass nor volume, by itself, can distinguish between substances.

7. Based on Student 1's explanation, the same substance composes both of the samples in which of the following pairs?

A. Samples A and B
B. Samples B and C
C. Samples C and D
D. Samples D and E

8. Based on Student 3's explanation, the same substance composes both of the samples in which of the following pairs?

F. Samples A and C
G. Samples B and E
H. Samples F and G
J. Samples G and H

9. Suppose that the temperature of Sample A is increased to 250°C at 1 atm of pressure. At 250°C, would Sample A be a solid or a liquid?

A. Solid, because the melting point of Sample A is 126°C.
B. Solid, because the melting point of Sample A is 747°C.
C. Liquid, because the melting point of Sample A is 126°C.
D. Liquid, because the melting point of Sample A is 747°C.

10. Consider the claim that 2 samples having the same density will always be composed of the same substance, regardless of the values of the other 4 properties. Which of the students, if any, would be likely to agree with this claim?

F. Students 1 and 2 only
G. Students 2, 3, and 4 only
H. All of the students
J. None of the students

11. Which of Students 2, 3, and 4 would be likely to agree that Sample A and Sample B are composed of the same substance?

A. Students 2 and 3 only
B. Students 2 and 4 only
C. Students 3 and 4 only
D. Students 2, 3, and 4

12. Consider the statement "Two samples that have the same mass, volume, density, and boiling point are composed of the same substance, even if the two samples have different melting points." Which of Students 2 and 4, if either, would be likely to agree with this statement?

F. Student 2 only
G. Student 4 only
H. Both Student 2 and Student 4
J. Neither Student 2 nor Student 4

13. Suppose that the temperature of Sample D is increased to 890°C at 1 atm of pressure. Will the sample's density be lower than or higher than it was at 20°C and 1 atm ?

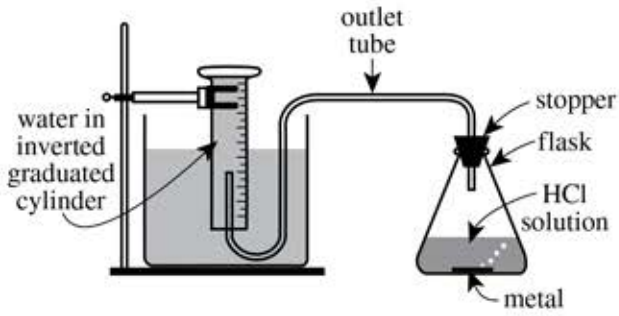
A. Lower; Sample D will be a gas, and gases generally have lower densities than do solids.
B. Lower; Sample D will be a liquid, and liquids generally have lower densities than do solids.
C. Higher; Sample D will be a gas, and gases generally have higher densities than do solids.
D. Higher; Sample D will be a liquid, and liquids generally have higher densities than do solids.

Passage III

When a solid metal (M) such as iron (Fe), nickel (Ni), or zinc (Zn) is placed in an aqueous hydrochloric acid (HCl) solution, a reaction that produces H_2 gas occurs:

$$M + 2HCl \rightarrow MCl_2 + H_2$$

Two experiments were conducted to study the production of H_2 in this reaction. The apparatus shown in the diagram below was used to collect the H_2 gas produced in each trial.



diagram

As H_2 was produced in the stoppered flask, it exited the flask through the outlet tube and displaced the water that had been trapped in the inverted graduated cylinder. (This displacement occurred because the H_2 did not dissolve in the water.) The volume of water displaced equaled the volume of gas (H_2 and water vapor) collected.

In each trial of the experiments, Steps 1–3 were performed:

1. The apparatus was assembled, and 25 mL of a 4 moles/L HCl solution was poured into the empty flask.
2. A selected mass of Fe, Ni, or Zn was added to the flask, and the stopper was quickly reinserted into the flask.
3. When H_2 production ceased, the volume of water that was displaced from the graduated cylinder was recorded.

The apparatus and its contents were kept at a selected temperature throughout Steps 2 and 3. The atmospheric pressure was 758 mm Hg throughout all 3 steps.

Experiment 1

In each trial, a selected mass of Fe, Ni, or Zn was tested at 30°C (see Figure 1).

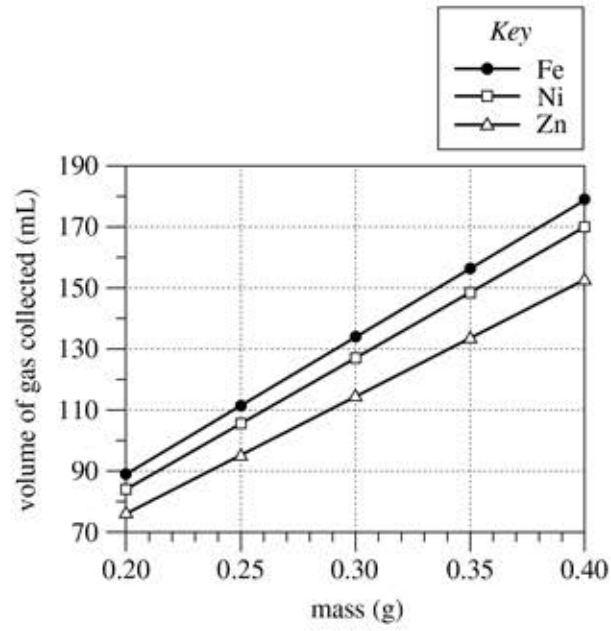


Figure 1

Experiment 2

In each trial, 0.30 g of Fe, Ni, or Zn was tested at a selected temperature (see Figure 2).

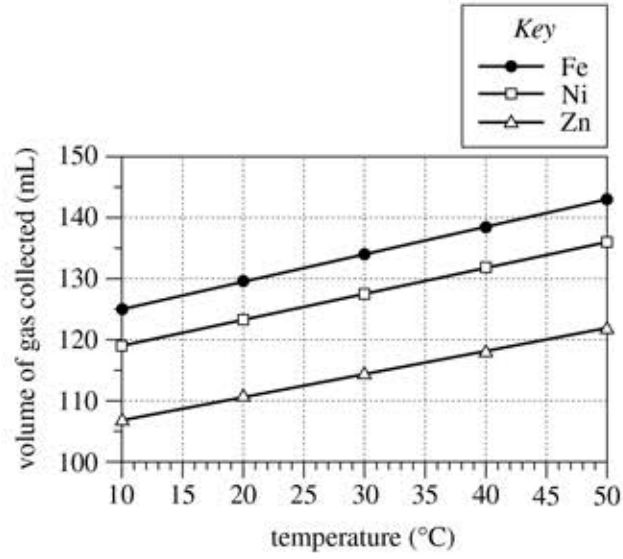


Figure 2

14. Consider the volume of gas collected in the trial in Experiment 2 for Ni at 30°C. The same approximate volume of gas was collected in the trial in Experiment 1 for what mass of Ni ?

F. 0.20 g
G. 0.25 g
H. 0.30 g
J. 0.35 g

15. How many temperatures were tested in Experiment 1, and how many temperatures were tested in Experiment 2 ?

	Experiment 1	Experiment 2
A.	1	1
B.	1	5
C.	5	1
D.	5	5

16. Which of the following statements describes a difference between Experiments 1 and 2 ? In Experiment 1:

F. only Fe was tested, but in Experiment 2, Fe, Ni, and Zn were tested.
G. Fe, Ni, and Zn were tested, but in Experiment 2, only Fe was tested.
H. the same mass value of each metal was tested, but in Experiment 2, multiple mass values of each metal were tested.
J. multiple mass values of each metal were tested, but in Experiment 2, the same mass value of each metal was tested.

17. Which of the following variables remained constant throughout both experiments?

A. Atmospheric pressure
B. Mass of metal
C. Temperature
D. Volume of gas collected

18. If a temperature of 5°C had been tested in Experiment 2, would the volume of gas collected for Zn more likely have been greater than 107 mL or less than 107 mL ?

F. Greater than 107 mL, because for a given metal, the volume of collected gas increased as the temperature decreased.
G. Greater than 107 mL, because for a given metal, the volume of collected gas increased as the temperature increased.
H. Less than 107 mL, because for a given metal, the volume of collected gas decreased as the temperature decreased.
J. Less than 107 mL, because for a given metal, the volume of collected gas decreased as the temperature increased.

19. Consider the balanced chemical equation in the passage. Based on this equation, if 10 moles of HCl are consumed, how many moles of H_2 are produced?

A. 5
B. 10
C. 15
D. 20

20. Suppose that the trial in Experiment 1 with 0.25 g of Zn is repeated, except that the inverted graduated cylinder is replaced by inverted test tubes, each completely filled with 60 mL of water. Based on Figure 1, how many test tubes will be needed to collect all the gas?

F. 1
G. 2
H. 3
J. 4

Passage IV

Figure 1 is a diagram of an *RLC circuit*. The circuit has a power supply and 3 components: a resistor (R), an inductor (L), and a capacitor (C).

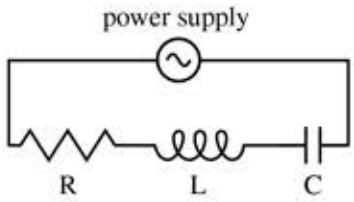


Figure 1

Electric current can flow through the circuit either clockwise (positive current) or counterclockwise (negative current). Figure 2 shows how the electric current in the circuit, I (in amperes, A), and the power supply voltage, V_S (in volts, V), both changed during a 20-millisecond (msec) time interval.

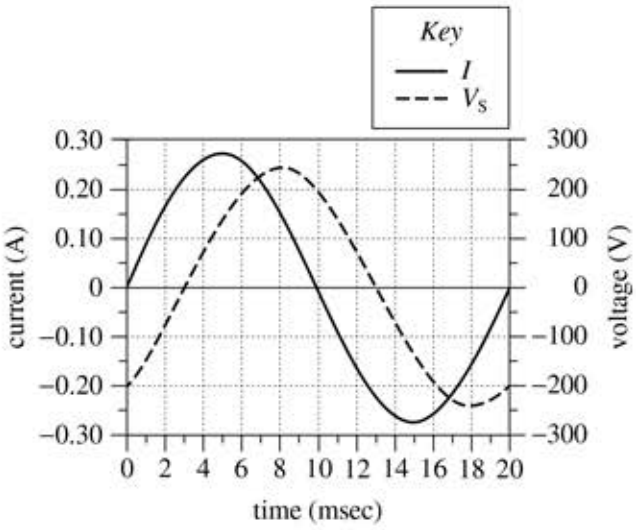


Figure 2

Figure 3 shows how the voltages across the components—V_R, V_L, and V_C, respectively—each changed during the same 20 msec time interval.

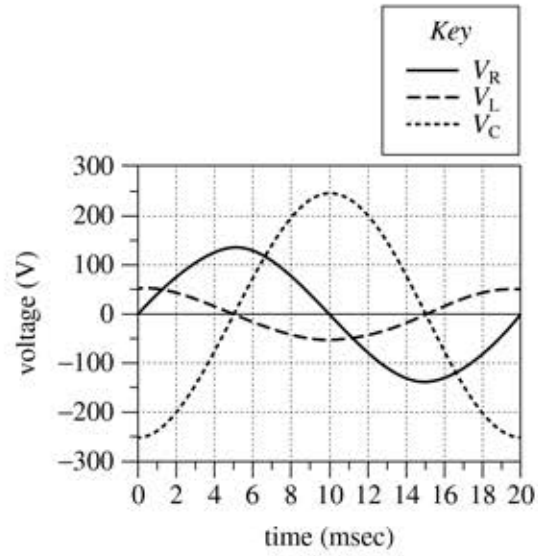


Figure 3

21. According to Figure 2, the maximum positive value of V_S was approximately:

A. 125 V.
B. 200 V.
C. 250 V.
D. 275 V.

22. A *period* is the time required for a wave to complete one full cycle. Based on Figure 3, the period for V_L was:

F. 5 msec.
G. 10 msec.
H. 20 msec.
J. 40 msec.

23. According to Figures 2 and 3, which voltage varied the *least* during the 20 msec interval?

A. V_S
B. V_R
C. V_L
D. V_C

24. *Polarity* refers to whether a voltage is positive or negative (a voltage of 0 V has no polarity and can be ignored). Based on Figures 2 and 3, which 2 voltages were always *opposite* in polarity?

F. V_R and V_L
G. V_R and V_S
H. V_L and V_C
J. V_L and V_S

25. Based on Figure 2, at which of the following times was the current in the circuit flowing counterclockwise?

A. 0 msec
B. 5 msec
C. 10 msec
D. 15 msec

26. The table below lists the electric charge (in microcoulombs, μC) stored on the capacitor at 3 different times during the 20 msec interval.

Time (msec)	Charge (μC)
7	0.51
10	0.87
13	0.51

Based on Figures 2 and 3, from time = 7 msec through time = 13 msec, did the charge on the capacitor more likely change in sync with I or with V_C ?

F. I; over that time interval, both the charge and I decreased and then increased.
G. I; over that time interval, both the charge and I increased and then decreased.
H. V_C; over that time interval, both the charge and V_C decreased and then increased.
J. V_C; over that time interval, both the charge and V_C increased and then decreased.

Passage V

Strains of bacteria carrying a genetic mutation that prevents them from synthesizing the amino acid *histidine* are called *His*$^-$. These strains of bacteria must absorb histidine from their environment in order to sustain their growth. Exposing His$^-$ strains of bacteria to *mutagens* (substances that induce DNA mutations) can cause new mutations that restore the ability of some bacteria to synthesize histidine. Any bacterium that regains the ability to synthesize histidine becomes *His*$^+$ and is known as a *His*$^+$ *revertant*.

The number of His$^+$ revertants in a population of bacteria can indicate the potential of a substance to be mutagenic in humans. Scientists tested 4 substances, each suspected to be a mutagen, on a His$^-$ strain of the bacteria *Salmonella typhimurium*.

Study

A sterile petri dish (Dish 1) containing a nutrient agar lacking histidine was prepared. Then, 1×10^8 cells of His$^-$ *S. typhimurium* were added to Dish 1 and evenly spread over the surface of the nutrient agar. These procedures were repeated for 4 more nutrient agar dishes (Dishes 2–5), except that the bacteria were mixed with 1 of the 4 suspected mutagens before being spread over the surface of the nutrient agar. Table 1 lists, for each of Dishes 2–5, the substance that was mixed with the bacteria before they were added to the dish.

Table 1

Dish	Substance
2	L
3	M
4	N
5	P

The 5 dishes were incubated at 37°C for 2 days. At the end of the incubation period, the number of colonies growing on the nutrient agar in each dish was determined (see Table 2).

Table 2

Dish	Number of colonies
1	2
2	14
3	25
4	107
5	6

27. Based on the results of the study, which of the suspected mutagens resulted in the greatest number of His$^+$ revertants in a dish?

A. Substance L
B. Substance M
C. Substance N
D. Substance P

28. Which dish in the study was intended to serve the purpose of testing whether some of the *S. typhimurium* cells became His$^+$ revertants without the addition of a mutagen?

F. Dish 1
G. Dish 2
H. Dish 3
J. Dish 4

29. Based on the results of the study, what is the order of the suspected mutagens, from the substance with the *least* potential to be mutagenic to the substance with the *most* potential to be mutagenic?

A. P, M, N, L
B. P, L, M, N
C. N, L, P, M
D. N, M, L, P

30. In the study, the scientists tested the effect of Substance P at a concentration of 5×10^{-9} g/mL. After the study, the scientists repeated their test of the effect of Substance P, but at 3 other concentrations. The 3 concentrations and their corresponding results are shown in the table below.

Concentration of Substance P	Number of colonies
10×10^{-9} g/mL	14
50×10^{-9} g/mL	54
100×10^{-9} g/mL	114

What is the relationship, if any, between the concentration of Substance P and its potential to cause mutations?

F. As the concentration of Substance P increases, its potential to cause mutations increases only.
G. As the concentration of Substance P increases, its potential to cause mutations decreases only.
H. As the concentration of Substance P increases, its potential to cause mutations first decreases and then increases.
J. There is no relationship between the concentration of Substance P and its potential to cause mutations.

31. Before bacteria were added to it, the dish that was intended to serve as the control dish in the study lacked which of the substances listed below?

I. Histidine
II. Nutrient agar
III. Suspected mutagen

A. II only
B. III only
C. I and II only
D. I and III only

32. Which of the following statements about the numbers of bacteria that regained the ability to synthesize histidine is consistent with the results of the study for Dishes 2 and 3 ? The number of bacteria that became His^+ revertants after exposure to:

F. Substance M was about 2 times the number of bacteria that became His^+ revertants after exposure to Substance L.
G. Substance L was about 2 times the number of bacteria that became His^+ revertants after exposure to Substance M.
H. Substance M was about 4 times the number of bacteria that became His^+ revertants after exposure to Substance L.
J. Substance L was about 4 times the number of bacteria that became His^+ revertants after exposure to Substance M.

33. The particular strain of *S. typhimurium* chosen for the study lacks normal DNA repair mechanisms. Which of the following statements gives the most likely reason this particular strain was chosen? The scientists:

A. did not want the bacteria in the study to synthesize any DNA.
B. did not want the bacteria in the study to synthesize any proteins.
C. wanted the bacteria in the study to be able to repair the mutations caused by the substances.
D. wanted the bacteria in the study to be unable to repair the mutations caused by the substances.

Passage VI

Three studies examined how the volume of runoff from melting ice is affected by wind speed and by the presence of sand beneath the ice.

In a lab kept at 18°C, runoff was collected from a plastic box containing melting ice. The box was tilted at 10° and had horizontal openings in its lower end. After flowing through the openings, the runoff fell into a trough (see diagram) and was conveyed to a measuring device.

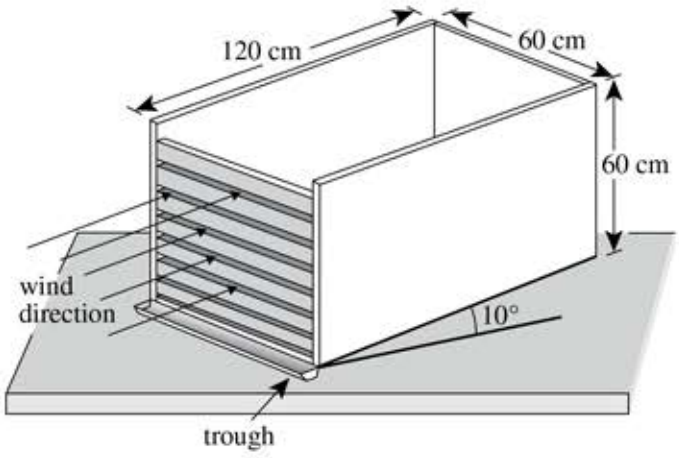


diagram of box

Study 1

In each of the first 3 of 4 trials, the following steps were carried out:

1. A 30 cm deep layer of a particular clean, dry sand was placed in the box.
2. A 30 cm deep layer of *chipped ice* (density 0.4 g/cm^3) was placed in the box on top of the layer of sand.
3. A fan was turned on to blow air at a constant speed onto the trough end of the box.
4. For the next 600 min, the volume of runoff collected over each 20 min period was measured.

The wind speed was 2.5 m/sec, 1.0 m/sec, and 0.5 m/sec in the first, second, and third trials, respectively.

In the fourth trial, all steps except Step 3 were carried out. (The fan was not turned on.)

The results of the 4 trials are shown in Figure 1.

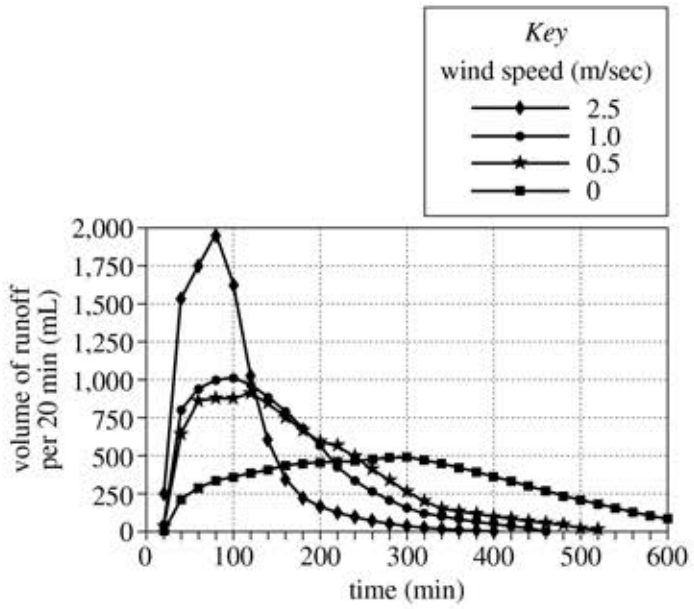


Figure 1

Study 2

The second trial of Study 1 was repeated. Then the second trial of Study 1 was again repeated, except that Step 1 was omitted. (No sand layer was placed in the box.) The results of the 2 trials are shown in Figure 2.

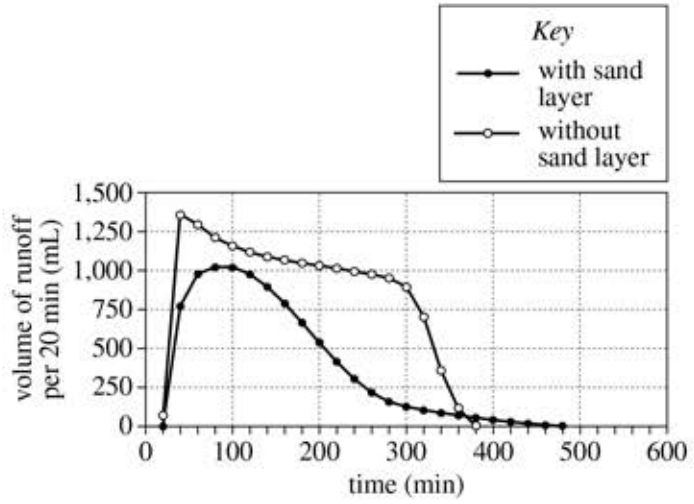


Figure 2

Figures adapted from Masahiko Hasebe and Takanori Kumekawa, "The Effect of Wind Speed on the Snowmelt Runoff Process: Laboratory Experiment." ©1994 by International Association of Hydrological Sciences Publishing.

34. The researchers conducting the studies chose to use a box made of a type of plastic rather than of wood to ensure that all of the water from the melting ice would flow from the box and into the trough. The researchers most likely made that choice because that type of plastic, unlike wood, is:

- **F.** porous and permeable, and therefore incapable of absorbing water.
- **G.** nonporous and impermeable, and therefore incapable of absorbing water.
- **H.** porous and permeable, and therefore capable of absorbing water.
- **J.** nonporous and impermeable, and therefore capable of absorbing water.

35. Suppose Study 2 had been repeated, except in a lab kept at −1°C. The total volume of runoff measured over the 600 min in the repeated study would most likely have been:

- **A.** near or at zero, because −1°C is below the freezing point of water.
- **B.** near or at zero, because −1°C is above the freezing point of water.
- **C.** greater than that in the original study, because −1°C is below the freezing point of water.
- **D.** greater than that in the original study, because −1°C is above the freezing point of water.

36. According to the results of Study 1, for which of the wind speeds did the runoff volume per 20 min decrease to zero from its maximum value *before* 500 min ?

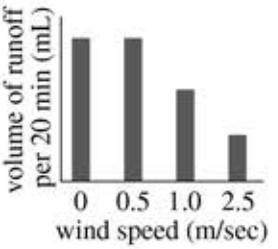
- **F.** 0 m/sec only
- **G.** 2.5 m/sec only
- **H.** 0.5 m/sec and 1.0 m/sec only
- **J.** 1.0 m/sec and 2.5 m/sec only

37. Compare the results of the 2 trials in Study 2. In which trial did the volume of runoff per 20 min reach a greater maximum value, and in which trial did the volume of runoff per 20 min decrease to zero from the maximum value in the shorter amount of time?

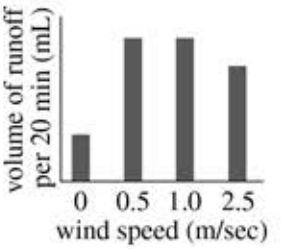
	greater maximum	shorter time to zero
A.	with sand layer	with sand layer
B.	with sand layer	without sand layer
C.	without sand layer	with sand layer
D.	without sand layer	without sand layer

38. The volume of runoff measured at 200 min in Study 1 for the 4 wind speeds is best represented by which of the following graphs?

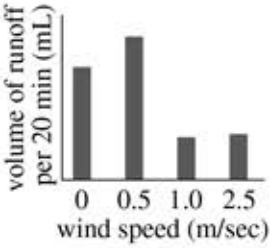
F.



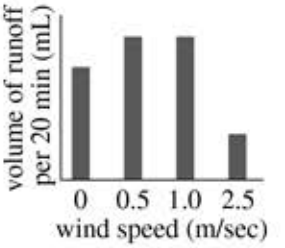
H.



G.



J.



39. Which factor was varied in Study 1 but kept the same in Study 2 ?

- **A.** Depth of sand layer
- **B.** Wind speed
- **C.** Tilt of box
- **D.** Type of material that melted

40. Based on the diagram and the description of Study 1, which of the following expressions would most likely be used to calculate the *volume* of the sand layer in the plastic box (before chipped ice was placed on top)?

- **F.** 30 cm × 60 cm × 60 cm
- **G.** 30 cm × 60 cm × 120 cm
- **H.** 60 cm × 60 cm × 60 cm
- **J.** 60 cm × 60 cm × 120 cm

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

[See Note on page 52.]