SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are seven 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

Scientists categorized each of the 300 pearly mussel species native to North America. If there were sufficient data to determine a species' risk of extinction, it was placed in 1 of 5 risk categories; otherwise, it was placed in a separate category (see Table 1).

Table 1

	Category	Percent of species
increasing risk of extinction ↑	Extinct	7
	Endangered	26
	Special concern	24
	Threatened	15
	Stable	24
	Insufficient data	4

Table 1 adapted from Upper Midwest Environmental Sciences Center, "Development of Landscape Models for Conservation of Freshwater Mussels in the Upper Mississippi River Basin." U.S. Geological Survey, 2003.

Zebra mussels (a nonnative species) are thought to damage pearly mussel populations in North America. Zebra mussels became abundant in the Hudson River estuary in late 1992. Figure 1 shows the number of native pearly mussels in the Hudson River estuary late in each year from 1992 through 2002.

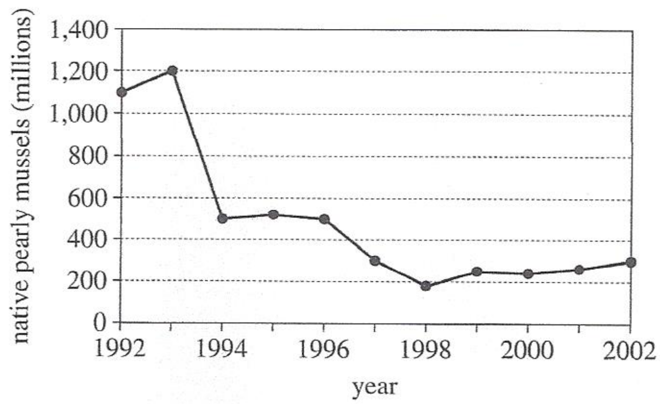


Figure 1

Figure 1 adapted from David Strayer, "Pearly mussels are well worth closer inspection." ©2004 by Poughkeepsie Journal.

1. According to Table 1, what percent of the pearly mussel species native to North America could not be placed in a category based on their risk of extinction?

A. 0%
B. 4%
C. 7%
D. 24%

2. Based on Figure 1, how many pearly mussels were most likely present in the Hudson River estuary when zebra mussels became abundant there?

   F. Less than 1,000 million
   G. Between 1,000 million and 1,200 million
   H. Between 1,200 million and 1,400 million
   J. More than 1,400 million

3. Based on Table 1, what percent of the pearly mussel species native to North America were the scientists able to place in a risk category but did not classify as extinct or stable?

   A. 7%
   B. 26%
   C. 50%
   D. 65%

4. Assume that zebra mussels *do* damage pearly mussel species native to North America. Based on Figure 1, if all the zebra mussels in the Hudson River estuary had been removed in 2002, the population of native pearly mussels in the estuary in 2005 most likely would have been:

   F. less than or equal to 25 million.
   G. between 25 million and 125 million.
   H. between 125 million and 225 million.
   J. greater than or equal to 225 million.

5. Which of the mussels, the zebra mussels or the pearly mussels, if either, would, when encountered in the Hudson River estuary, be considered an invasive species?

   A. Zebra mussels only
   B. Pearly mussels only
   C. Both zebra mussels and pearly mussels
   D. Neither zebra mussels nor pearly mussels

Passage II

Physics students studied electrical current and resistance using the electrical circuit shown in Figure 1 below.

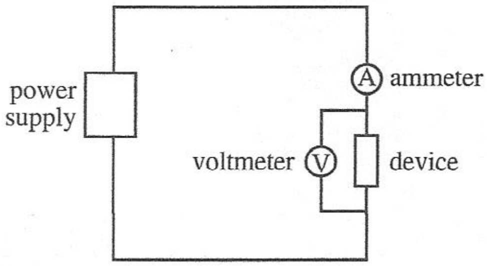


Figure 1

The students determined the electrical current, I, flowing through each of 3 devices—a resistor, a lightbulb, and a diode—for various voltages, $\mathscr{E}$, across the device. At each voltage, the students also determined the resistance, R, of each device.

Figure 2 shows graphs of I, in milliamperes (mA), versus $\mathscr{E}$, in volts (V), for each device. Figure 3 shows graphs of R, in ohms (Ω), versus $\mathscr{E}$ for each device.

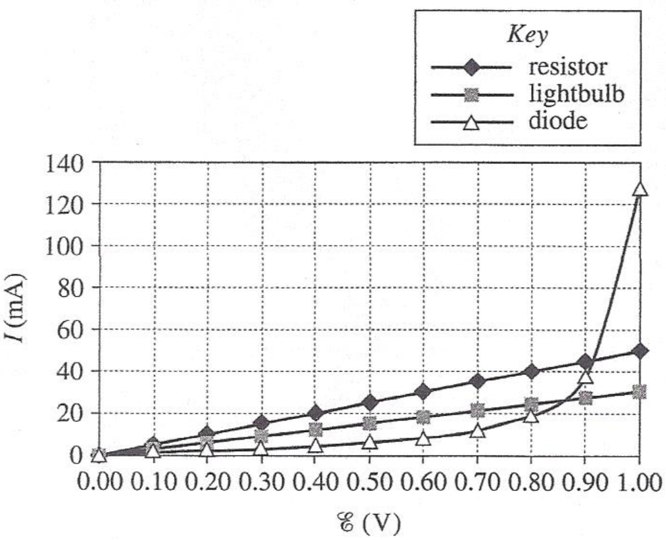


Figure 2

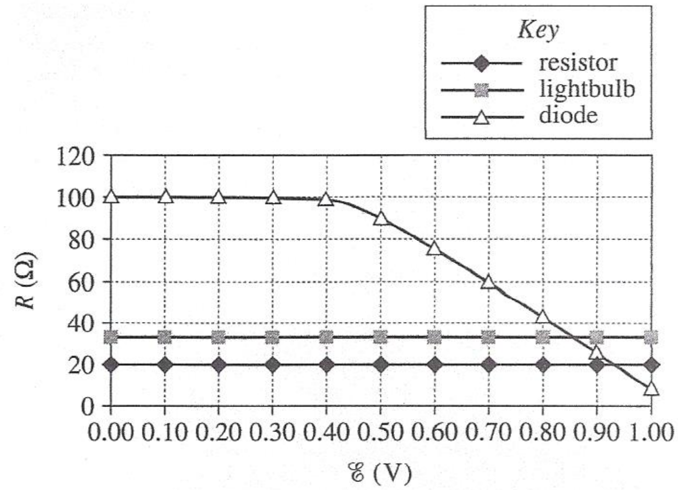


Figure 3

6. Based on Figure 2, at 1.10 V, I for the diode would most likely be:
   - **F.** less than 20 mA.
   - **G.** between 20 mA and 80 mA.
   - **H.** between 80 mA and 130 mA.
   - **J.** greater than 130 mA.

7. For each of the devices tested, as $\mathscr{E}$ increased, I:
   - **A.** increased only.
   - **B.** decreased only.
   - **C.** varied, but with no general trend.
   - **D.** remained the same.

8. For a device in an electrical circuit that follows *Ohm's law*, the ratio of the voltage across the device to the current flowing through the device is constant. Based on Figure 2, which of the 3 devices followed Ohm's law throughout the interval from $\mathcal{E} = 0.00$ V to $\mathcal{E} = 1.00$ V ?

F. Resistor only
G. Diode only
H. Resistor and lightbulb only
J. Lightbulb and diode only

9. Based on Figures 2 and 3, when *R* for the diode equaled 60 Ω, *I* for the diode was closest to which of the following?

A. 12 mA
B. 20 mA
C. 38 mA
D. 50 mA

10. Based on Figure 3, the diode best *conducted* electricity when $\mathcal{E}$ for the diode equaled which of the following?

F. 0.20 V
G. 0.40 V
H. 0.60 V
J. 0.80 V

Passage III

Suppose a ball is dropped from a height H above a horizontal surface. The ball falls straight down until it collides with the surface; then it bounces straight up, attaining a maximum height y before it begins to fall again. The *coefficient of restitution*, C, for the collision equals $\frac{y}{H}$. Therefore:

$$y = CH$$

Physics students went to a high-altitude laboratory to conduct studies of C for various balls bouncing off different horizontal surfaces. The air temperature and air pressure were constant in the laboratory throughout the studies.

Study 1

The students dropped a racquetball from various H onto a particular horizontal surface, and after each drop they measured y. Then they graphed y versus H (see Figure 1); C equaled the slope of the graph.

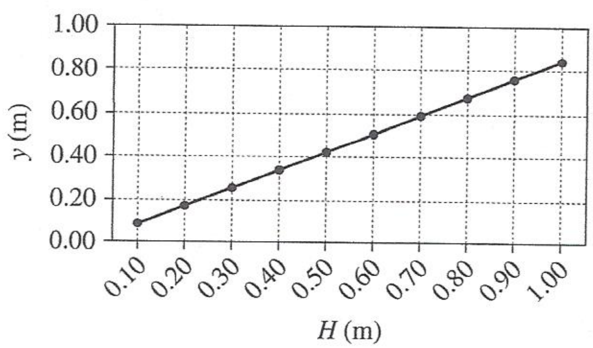


Figure 1

Study 2

The students repeated the procedure in Study 1 and determined C for various balls dropped onto both a bare concrete surface and a concrete surface covered with a thin layer of foam. Both surfaces were horizontal. The results are given in Table 1.

Table 1

Ball	C for ball's collision with: bare concrete surface	foam-covered concrete surface
Racquetball	0.85	0.76
Golf ball	0.82	0.79
Tennis ball	0.75	0.66
Steel ball	0.65	0.42
Baseball	0.55	0.33

11. Suppose that, in an additional trial in Study 1, H had equaled 0.75 m. Based on the results of the study, y would have been closest to which of the following values?

A. 0.45 m
B. 0.55 m
C. 0.65 m
D. 0.75 m

12. Suppose, while testing a particular ball during Study 2, the students had obtained a value for C that was greater than 1.0. Which of the following statements would best explain this result?

F. The ball was not spherical in shape.
G. The ball broke upon impact.
H. The ball was thrown downward rather than dropped.
J. The ball stuck to the surface upon impact rather than bouncing upon impact.

13. Suppose, in an additional trial in Study 2, the students had dropped a ball onto the bare concrete surface, and the ball stuck to the surface without bouncing. C for this collision would have equaled what value?

A. 0.0
B. 0.5
C. 1.0
D. Cannot be determined from the given information

14. To determine if the surface tested in Study 1 was more likely bare concrete or foam-covered concrete, one would compare C in Study 1 with each C in Study 2 for the:

F. racquetball.
G. golf ball.
H. tennis ball.
J. baseball.

15. Suppose that in Study 2 the steel ball had been dropped onto the bare concrete surface and the foam-covered concrete surface from a height of 2.00 m. Approximately how much lower or higher would the steel ball have bounced after its collision with the bare concrete surface than after its collision with the foam-covered concrete surface?

A. 0.5 m lower
B. 1.0 m lower
C. 0.5 m higher
D. 1.0 m higher

16. Which of the following statements best explains why the students conducted the studies at the location referred to in the passage? The students most likely wanted to:

F. decrease the force exerted by gravity on the balls tested.
G. decrease the force exerted by air resistance on the balls tested.
H. increase the force exerted by gravity on the balls tested.
J. increase the force exerted by air resistance on the balls tested.

Passage IV

A researcher investigated the growth of 6 species of floodplain plants. Each species was classified as either flood-sensitive (S) or flood-tolerant (T) (see Table 1).

Table 1

Plant species	Abbreviation	Classification
Achillea ptarmica *Achillea millefolium*	Ap Am	T S
Festuca arundinacea *Festuca rubra*	Fa Fr	T S
Rumex palustris *Rumex thyrsiflorus*	Rp Rt	T S

Experiment

Seeds from each of the 6 species were germinated in a growth chamber maintained at 25.5°C during the day and at 10°C at night.

After germination, the seedlings of each species were planted in separate 0.5 L pots and grown for 4 weeks. The seedlings were watered 3 times per week.

At the end of the 4 weeks, each plant was repotted into its own 4 L pot containing a substrate composed of a 4:1 mixture, by mass, of sand to compost. The plants were grown for 2 more weeks; during this time, they were watered 3 times per week.

Next, the potted plants were placed in plastic tubs such that each tub contained 8 plants of each species. Each tub of plants was subjected to a different treatment (see Table 2) for 3 weeks.

Table 2

Treatment	Procedure
1	Pots were watered 3 times per week. Water level was always below the substrate surface.
2	Water level was maintained at the substrate surface.
3	Water level was maintained 2 cm above the substrate surface.
4	Water level was maintained 6 cm above the substrate surface.

At the end of the 3-week treatments, the plants were harvested, and their roots were washed. The roots were separated from the shoots, and then both were dried at 70°C for 48 hr. The average dry shoot biomass per plant and the average dry root biomass per plant were determined for each species and treatment combination (see Figures 1 and 2, respectively).

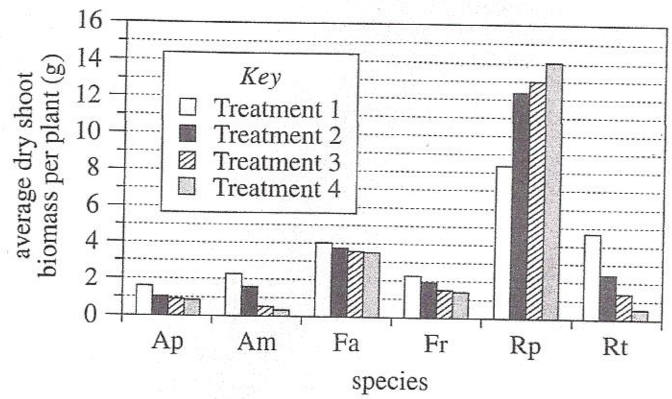


Figure 1

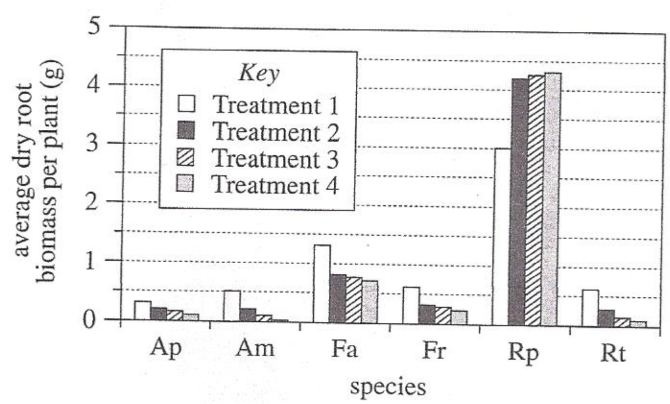


Figure 2

Figures 1 and 2 adapted from C. Jansen, H. M. Van De Steeg, and H. De Kroon, "Investigating a Trade-Off in Root Morphological Responses to a Heterogeneous Nutrient Supply and to Flooding." ©2005 by British Ecological Society.

17. Which treatment resulted in the greatest average dry shoot biomass per plant for Rp plants?

A. Treatment 1
B. Treatment 2
C. Treatment 3
D. Treatment 4

18. The roots were washed after harvest most likely to ensure that the:

F. roots had an opportunity to sprout after the plants were repotted.
G. intracellular water could be removed from the shoot biomass during the drying process.
H. substrate particles attached to the roots were not included in the root biomass measurements.
J. shoots were removed from the plants prior to the drying process.

19. When the water level was maintained 2 cm above the substrate surface, which floodplain plants, the T species plants or the S species plants, had the greater average dry root biomass per plant?

A. The T species plants; the average dry root mass per plant was greater for Ap plants than for Am plants, greater for Fa plants than for Fr plants, and greater for Rp plants than for Rt plants.
B. The T species plants; the average dry root mass per plant was greater for Am plants than for Ap plants, greater for Fr plants than for Fa plants, and greater for Rt plants than for Rp plants.
C. The S species plants; the average dry root mass per plant was greater for Ap plants than for Am plants, greater for Fa plants than for Fr plants, and greater for Rp plants than for Rt plants.
D. The S species plants; the average dry root mass per plant was greater for Am plants than for Ap plants, greater for Fr plants than for Fa plants, and greater for Rt plants than for Rp plants.

20. Which of the following pieces of equipment was most likely used to collect the data presented in Figure 1 ?

F. Microscope
G. Balance
H. Hydrometer
J. Ruler

21. Which of the following comparisons of the shoot biomass and the root biomass produced by S and T floodplain plants is best supported by the results of the experiment? Regardless of the water level:

A. both S and T plants produce, on average, more shoot than root biomass per plant.
B. both S and T plants produce, on average, more root than shoot biomass per plant.
C. S plants produce, on average, more shoot than root biomass per plant, whereas T plants produce, on average, more root than shoot biomass per plant.
D. S plants produce, on average, more root than shoot biomass per plant, whereas T plants produce, on average, more shoot than root biomass per plant.

22. The plants investigated in the experiment were from how many different genuses?

F. 2
G. 3
H. 4
J. 6

Passage V

Students were given unknown aqueous acid solutions UAX, UAY, and UAZ. Each solution had an acid concentration of 0.100 mole/L but contained a different acid. The students were also given Table 1, which gives the pK_a of each of 5 acids (the lower the pK_a, the stronger the acid).

Table 1

Acid	pK_a
Pyruvic	2.5
Chloroacetic	2.9
Iodoacetic	3.2
Formic	3.7
Acetic	4.8

In a *titration*, the *titrant* (a solution of known identity and concentration) is slowly added to the *analyte* (a solution of unknown identity or concentration). Students used titration to attempt to identify the acid present in UAX, UAY, and UAZ.

Experiment 1

A 0.100 mole/L aqueous sodium hydroxide (NaOH, a base) solution was added to a *buret* (a graduated tube with a valve at the bottom that can be opened to dispense precise volumes of liquid). The initial volume of solution in the buret was recorded. A beaker containing 20.00 mL of UAX was placed under the buret. A pH probe was placed in the beaker. Then 25.00 mL of the NaOH solution was added in small increments to the acid solution while the acid solution was continuously stirred. After each addition, the pH of the solution in the beaker was recorded (see Figure 1).

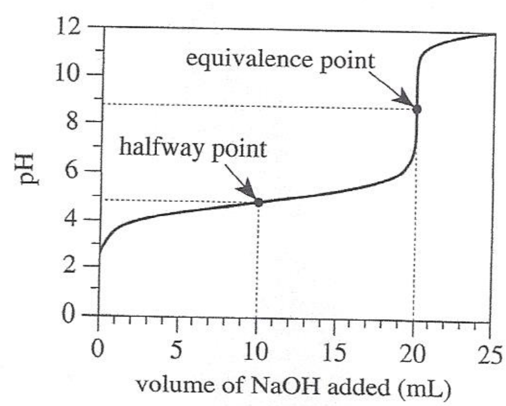


Figure 1

In Figure 1, the *equivalence point* indicates the volume of NaOH solution needed to react with all the acid in the solution in the beaker. At the *halfway point*, the volume of NaOH solution added is half of the volume needed to reach the equivalence point, and the pH of the solution in the beaker equals the pK_a of the acid in the solution.

Experiment 2

The procedure from Experiment 1 was repeated with UAY instead of UAX (see Figure 2).

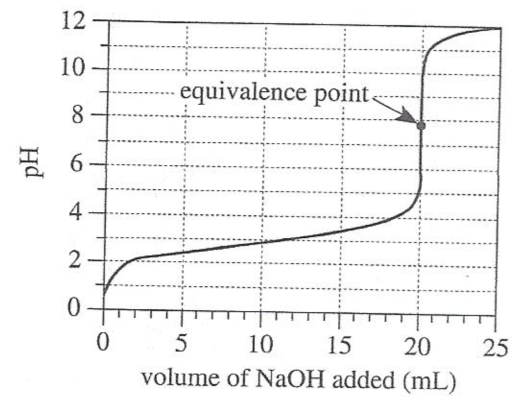


Figure 2

Experiment 3

The procedure from Experiment 1 was repeated with UAZ instead of UAX (see Figure 3).

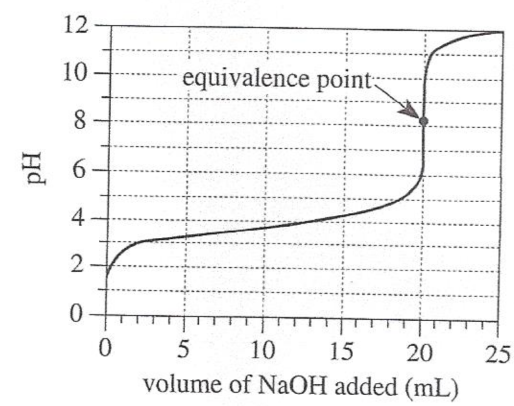
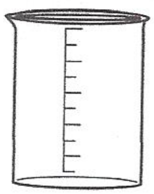
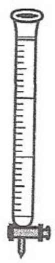


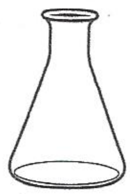
Figure 3

23. Based on the description of Experiment 1, which of the following diagrams best shows the apparatus that was used to dispense the titrant?

A. 

C. 

B. 

D. 

24. Which of the following statements describes a difference between Experiments 1 and 3 ?

F. In Experiment 1, the analyte was stirred; in Experiment 3, the analyte was not stirred.
G. In Experiment 1, the titrant was stirred; in Experiment 3, the titrant was not stirred.
H. The analyte in Experiment 1 was different from the analyte in Experiment 3.
J. The titrant in Experiment 1 was different from the titrant in Experiment 3.

25. *Hydrazoic acid* is a weaker acid than is formic acid but is a stronger acid than is acetic acid. Based on Table 1, the pK_a of hydrazoic acid is:

A. less than 3.2.
B. between 3.2 and 3.7.
C. between 3.7 and 4.8.
D. greater than 4.8.

26. In Experiment 2, the solution in the beaker was neutral when the volume of NaOH added was at a value between:

F. 9 mL and 11 mL.
G. 13 mL and 15 mL.
H. 15 mL and 17 mL.
J. 19 mL and 21 mL.

27. A student claimed that the acid in UAX is pyruvic acid. Based on Table 1 and Figure 1, this claim is *incorrect* because the pK_a of pyruvic acid is:

A. less than was the pH at the equivalence point.
B. greater than was the pH at the equivalence point.
C. less than was the pH at the halfway point.
D. greater than was the pH at the halfway point.

28. Suppose Experiment 3 is repeated, but the concentration of the NaOH solution is 0.200 mole/L. Will the volume of NaOH added at the halfway point and at the equivalence point be less than, greater than, or equal to the corresponding results shown in Figure 3 ?

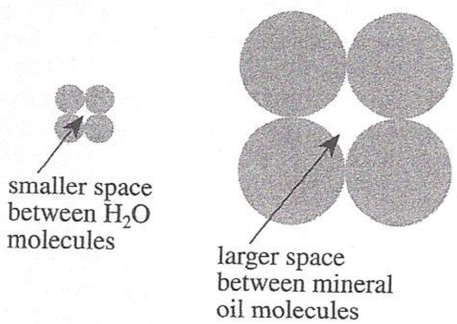
	halfway point	equivalence point
F.	less	less
G.	greater	less
H.	greater	greater
J.	equal	equal

Passage VI

A teacher showed 2 beakers to a chemistry class. One beaker contained mineral oil and the other contained H_2O. Solid iodine was added to each beaker. The solid iodine quickly dissolved in the mineral oil, which turned pink. The solid stayed at the bottom of the H_2O, which remained colorless. The teacher asked 3 students to explain these results.

Student 1

Mineral oil is made up of very large molecules, while H_2O is made up of very small molecules. Thus, the spaces between mineral oil molecules are much larger than the spaces between H_2O molecules (see figure).



For a solid to dissolve in a solvent, its molecules must squeeze in between solvent molecules. The *molecular mass* (the mass of 1 molecule in atomic mass units, amu) of a substance is a good indicator of molecular size, so if a solid has a molecular mass less than that of a solvent, it will most likely dissolve in the solvent. Therefore, the iodine dissolved in the mineral oil, but not in the H_2O.

Student 2

An H_2O molecule is *polar* because it has a region of positive charge and a region of negative charge. *Nonpolar* molecules, like those that make up mineral oil, do not have differently charged regions. Polar molecules are attracted to each other, and nonpolar molecules are attracted to each other, but polar molecules repel nonpolar molecules. Thus, polar solids dissolve in polar solvents, and nonpolar solids dissolve in nonpolar solvents. Therefore, the iodine dissolved in the mineral oil, but not in the H_2O. Molecular size is unrelated to solubility.

Student 3

Student 2 is correct, but with one exception. Nonpolar molecules are actually strongly attracted to polar molecules. The reason that nonpolar substances don't dissolve in polar substances is that polar molecules are too strongly attracted to each other to allow nonpolar molecules to come between them. If a drop of mineral oil is placed on the surface of a pan full of H_2O, the drop will spread to form the thinnest layer possible in order to maximize contact with H_2O molecules.

29. Which of the following terms best describes the mixture of iodine and solvent in each of the beakers at the end of the teacher's demonstration?

	iodine and mineral oil	iodine and H_2O
A.	heterogeneous	heterogeneous
B.	heterogeneous	homogeneous
C.	homogeneous	heterogeneous
D.	homogeneous	homogeneous

30. Based on Student 1's explanation, is it likely that solid H_2O would be soluble in mineral oil?

- **F.** Yes, because the solute molecules and the solvent molecules are nonpolar.
- **G.** Yes, because H_2O molecules are much smaller than mineral oil molecules.
- **H.** No, because the solute molecules are polar and the solvent molecules are nonpolar.
- **J.** No, because H_2O molecules are much larger than mineral oil molecules.

31. How would Student 1 most likely rank the 3 substances used in the demonstration, from the substance with the smallest molecular mass to the substance with the largest molecular mass?

- **A.** Iodine < H_2O < mineral oil
- **B.** H_2O < iodine < mineral oil
- **C.** Mineral oil < iodine < H_2O
- **D.** Mineral oil < H_2O < iodine

32. In Student 2's explanation, the sentence "Therefore, the iodine dissolved in the mineral oil, but not in the H_2O" implied that iodine molecules are:

- **F.** nonpolar.
- **G.** polar.
- **H.** smaller than H_2O molecules.
- **J.** larger than H_2O molecules.

33. Suppose it were observed that mineral oil molecules were smaller than iodine molecules. What impact, if any, would this observation have on Student 3's explanation?

- **A.** It would prove that the explanation is correct.
- **B.** It would support the explanation, but not prove that the explanation is correct.
- **C.** It would weaken the explanation, but not prove that the explanation is incorrect.
- **D.** It would have no impact on the explanation.

34. Paraffin wax is a nonpolar solid and acetic acid is a polar solvent. Based on Student 3's explanation, would paraffin wax be soluble in acetic acid?

F. Yes, because the paraffin wax molecules would be strongly attracted to the acetic acid molecules.
G. Yes, because the paraffin wax molecules would be more attracted to each other than to the acetic acid molecules.
H. No, because the paraffin wax molecules would be repelled by the acetic acid molecules.
J. No, because the acetic acid molecules would be more attracted to each other than to the paraffin wax molecules.

35. The nonpolar solid 9,10-diphenylanthracene has a molecular mass of 330 amu and readily dissolves in benzene. Benzene is a nonpolar solvent with a molecular mass of 78 amu. These observations are *inconsistent* with the explanation(s) put forth by:

A. Student 1 only.
B. Student 2 only.
C. Student 1 and Student 2 only.
D. Student 2 and Student 3 only.

Passage VII

Radar observations of Saturn's moon Titan have revealed landforms that resemble longitudinal sand dunes found in some deserts on Earth. Such dunes are produced when sand-size solid particles are deposited in linear, parallel piles (see Figure 1). Figure 2 shows the average dune spacing and average dune height for each of a number of areas of dunes on Titan and in 4 deserts on Earth (Deserts A–D). Figure 3 shows plots of the *surface elevation* (elevation above a horizontal reference plane) across a 25 km wide perpendicular cross section of dunes on Titan and in Desert A.

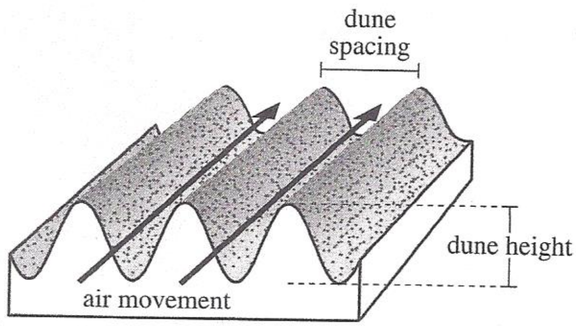
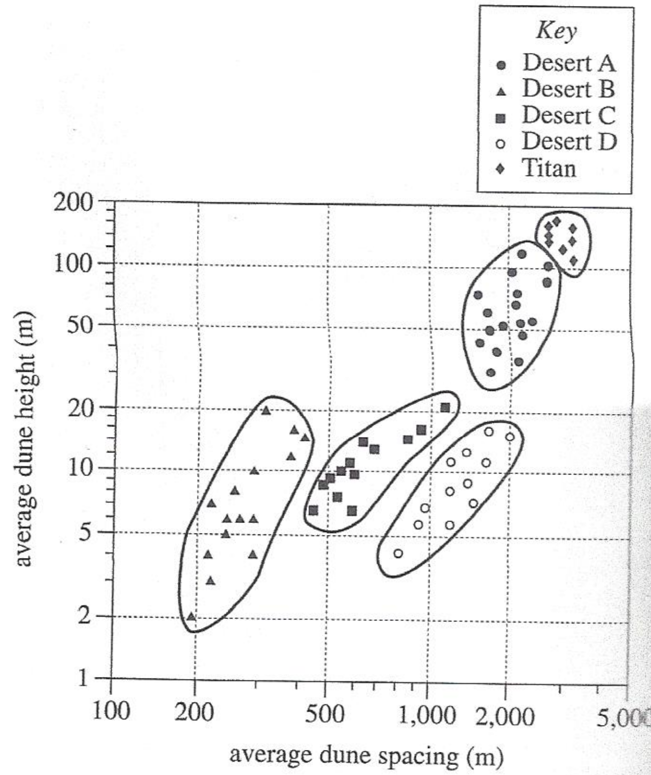


Figure 1



Note: Each symbol on the graph represents data for a different area of dunes in a desert or on Titan.

Figure 2

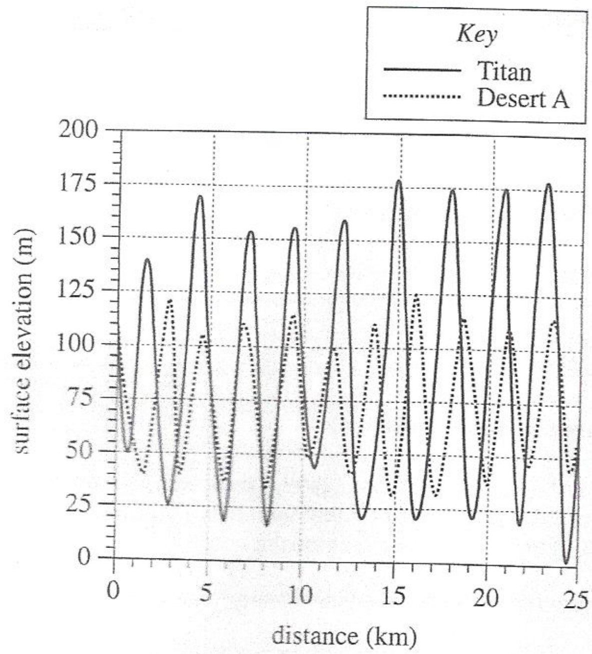


Figure 3

Figure 3 adapted from R. D. Lorenz et al., "The Sand Seas of Titan: Cassini RADAR Observations of Longitudinal Dunes." ©2006 by the American Association for the Advancement of Science.

36. According to Figure 2, which of the following average dune spacings and average dune heights would be most likely for an area of Desert D dunes?

	dune spacing (m)	dune height (m)
F.	500	2
G.	500	7
H.	1,000	2
J.	1,000	7

37. Assume that for the dunes represented in Figure 2, as average wind speed increases, average dune height increases. Did Desert A or Desert B more likely have the greater average wind speed?

A. Desert A, because the areas in that desert had greater average dune heights.
B. Desert A, because the areas in that desert had lesser average dune heights.
C. Desert B, because the areas in that desert had greater average dune heights.
D. Desert B, because the areas in that desert had lesser average dune heights.

38. According to Figure 3, across the 25 km wide cross section of dunes on Titan and in Desert A, how does the surface elevation of the Titan dunes differ, if at all, from the surface elevation of the Desert A dunes? The surface elevation of the Titan dunes is:

F. the same at all distances.
G. greater at all distances.
H. less at all distances.
J. greater at some distances but less at other distances.

39. Consider in Figure 2 the greatest average dune height shown for an area of Titan dunes. That height is how many times higher than the greatest average dune height shown for an area of Desert C dunes?

A. Less than 2 times as high
B. Between 2 and 3 times as high
C. Between 3 and 5 times as high
D. More than 5 times as high

40. The 2 quantities for dunes that are defined in Figure 1—dune spacing and dune height—are directly analogous to which 2 quantities for electromagnetic waves?

	dune spacing	dune height
F.	amplitude	wavelength
G.	wavelength	amplitude
H.	frequency	amplitude
J.	wavelength	frequency

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.