

SCIENCE TEST

35 Minutes—40 Questions

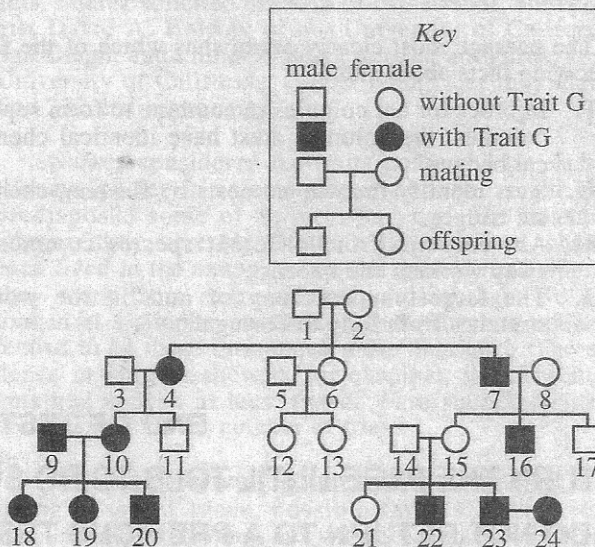
DIRECTIONS: There are several passages in this test. Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

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

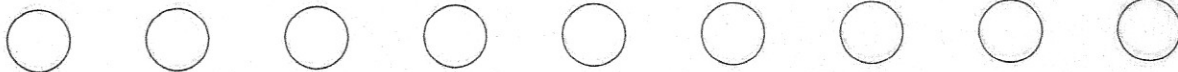
Passage I

The figure below is a pedigree that shows the inheritance of a trait, Trait G, in a family. The presence of Trait G in an individual is determined entirely by Gene G. Gene G has 2 alleles: *G*, which is dominant, and *g*, which is recessive.

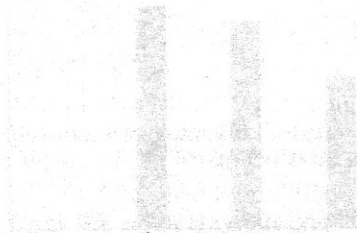
Each individual represented in the pedigree was assigned a number (shown below the symbol for the individual) for reference. Scientists determined that the Gene G genotype of Individual 20 is *gg* and that the Gene G genotype of Individual 21 is *Gg*. Based on this information, the scientists concluded that Trait G is a recessive trait.



- How many generations are shown in the figure?
 - 3
 - 4
 - 22
 - 24
- Based on the figure, the 2 individuals in which of the following pairs most likely have the greatest genetic similarity across their genomes?
 - Individual 3 and Individual 4
 - Individual 12 and Individual 13
 - Individual 16 and Individual 24
 - Individual 18 and Individual 21
- Suppose that Individual 23 and Individual 24 have 4 biological children. Based on the figure, how many of the children, if any, have Trait G?
 - 0
 - 1
 - 3
 - 4
- According to the figure, how many of the grandchildren of Individual 1 and Individual 2, if any, have Trait G?
 - 0
 - 1
 - 2
 - 7



5. Based on the figure, is it likely that Trait G is a sex-linked trait?
- A. Yes, because mothers with Trait G always passed Trait G to their sons.
 - B. Yes, because mothers with Trait G did not always pass Trait G to their sons.
 - C. No, because mothers with Trait G always passed Trait G to their sons.
 - D. No, because mothers with Trait G did not always pass Trait G to their sons.
6. Based on the information provided, will an individual with the Gene G genotype Gg have Trait G ?
- F. Yes, because Trait G is a dominant trait.
 - G. Yes, because Trait G is a recessive trait.
 - H. No, because Trait G is a dominant trait.
 - J. No, because Trait G is a recessive trait.



Genotype	Phenotype
GG	Has Trait G
Gg	Has Trait G
gg	Does not have Trait G

Passage II

Heliconia metallica is a plant found in the understory of tropical rain forests. (The *understory* is the area below the forest canopy.) *H. metallica* flowers are normally pollinated by hummingbirds. The flowers can be *self-pollinated* (egg and pollen are from the same *H. metallica* plant) or *cross-pollinated* (egg and pollen are from different *H. metallica* plants). The following study was conducted to investigate the effects of different pollination treatments on fruit production and seed mass in a population of *H. metallica*.

Study

Before pollination could occur, the *anthers* (pollen-producing structures) were removed from each of 400 *H. metallica* flowers. Then, the flowers were covered with nylon bags to prevent the normal pollinators from pollinating the flowers. The covered flowers were divided equally into 4 groups (Groups 1–4), and each group received a different pollination treatment (see Table 1). Four weeks after the pollination treatments, the percent of flowers that produced fruit and the average mass per seed were determined for each group (see Figures 1 and 2, respectively).

Group	Pollination treatment
1	self-pollination*
2	cross-pollination with pollen collected from a single donor <i>H. metallica</i> plant
3	cross-pollination with a mixture of pollen collected from 6 donor <i>H. metallica</i> plants
4	no pollination

*Each flower was pollinated with pollen from its removed anthers.

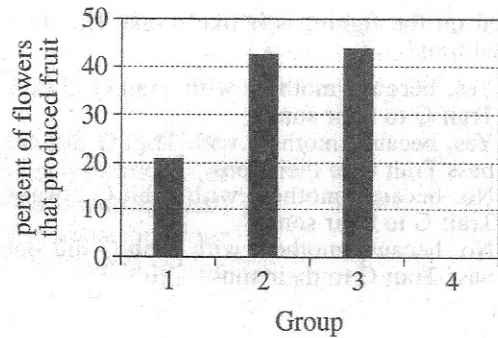


Figure 1

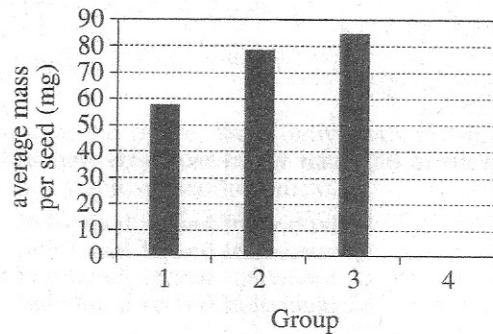


Figure 2

Table and figures adapted from Matthias Schleuning et al., "Effects of Inbreeding, Outbreeding, and Supplemental Pollen on the Reproduction of a Hummingbird-pollinated Clonal Amazonian Herb." ©2010 by The Author(s).

7. The data that were averaged to produce the results shown in Figure 2 were most likely collected using which of the following pieces of equipment?
- Balance
 - pH meter
 - Telescope
 - Thermometer
8. One of the questions about *H. metallica* plants that the study was designed to answer was which of the following?
- Does the location of the plants in the understory of tropical rain forests determine whether the flowers are self-pollinated or cross-pollinated?
 - Are the percent of flowers that produce fruit and the average mass per seed different when flowers are self-pollinated than when flowers are cross-pollinated?
 - How long after the plants are pollinated does the fruit ripen?
 - Are the flowers normally pollinated by hummingbirds?
9. The pollination treatments received by Groups 1 and 2 differed in which of the following ways? The pollen received by each Group 1 flower was:
- from the same plant as the flower, whereas the pollen received by each Group 2 flower was from a different plant than the flower.
 - from a different plant than the flower, whereas the pollen received by each Group 2 flower was from the same plant as the flower.
 - collected from 1 plant, whereas the pollen received by each Group 2 flower was collected from 6 plants.
 - collected from 6 plants, whereas the pollen received by each Group 2 flower was collected from 1 plant.
10. For any group, the value shown in Figure 1 was most likely calculated using which of the following expressions?
- $\frac{\text{number of seeds}}{\text{total seed mass}} \times 100$
 - $\frac{\text{total seed mass}}{\text{number of seeds}} \times 100$
 - $\frac{\text{number of flowers producing fruit}}{\text{total number of flowers}} \times 100$
 - $\frac{\text{total number of flowers}}{\text{number of flowers producing fruit}} \times 100$
11. The anthers were most likely removed from the flowers for the purpose of ensuring that the flowers:
- would spontaneously self-pollinate.
 - would not spontaneously self-pollinate.
 - would be pollinated by hummingbirds.
 - would not be pollinated by hummingbirds.
12. Do the results of the study indicate that the nylon bags successfully prevented the normal pollinators from pollinating the *H. metallica* flowers?
- Yes; only 20% of the flowers receiving the self-pollination treatment produced fruit.
 - Yes; none of the flowers receiving the no pollination treatment produced fruit.
 - No; only 20% of the flowers receiving the self-pollination treatment produced fruit.
 - No; none of the flowers receiving the no pollination treatment produced fruit.
13. What was the total mass of the seeds produced by the Group 3 flowers?
- 0 mg
 - 45 mg
 - 85 mg
 - Cannot be determined from the given information

Passage III

When 2 types of bacteria found in the soil of a *wetland* (land having a high water table) break down organic matter, gases are generated. *Aerobic bacteria*, which require O_2 , generate CO_2 . *Anaerobic bacteria*, which require little or no O_2 , generate CH_4 .

Study

At the beginning of a particular summer, 3 soil sections, each 1.5 m long, 1 m wide, and 0.6 m deep, were removed intact from the surface of each of 2 wetlands—a *bog* and a *fen*—after all live plants had been removed from the sections. Each section was placed in a separate 100 L tank having sides and a lid made entirely of glass. An instrument to measure gas emissions was mounted on the underside of the lid, above the soil. All the tanks were placed at an outdoor site near the wetlands.

Different amounts of water were added to the 3 tanks containing bog soil sections to produce a water table (WT) 1 cm above the surface (+1 cm) of the first soil section, a WT 10 cm below the surface (–10 cm) of the second soil section, and a WT 20 cm below the surface (–20 cm) of the third soil section. This procedure was repeated for the 3 tanks containing fen soil sections. All the lids were then closed.

Over the next 3 months, gas emissions from each soil section were measured, in moles of carbon per square meter ($mol\ C/m^2$). Throughout this period, the temperature inside the tanks was kept the same as the outdoor temperature. Figure 1 shows the total emission of CO_2 and the total emission of CH_4 from each bog soil section due to bacterial activity; Figure 2 does the same for each fen soil section.

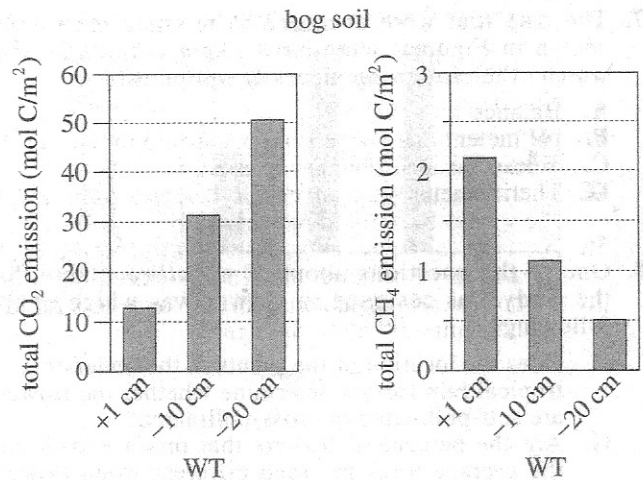


Figure 1

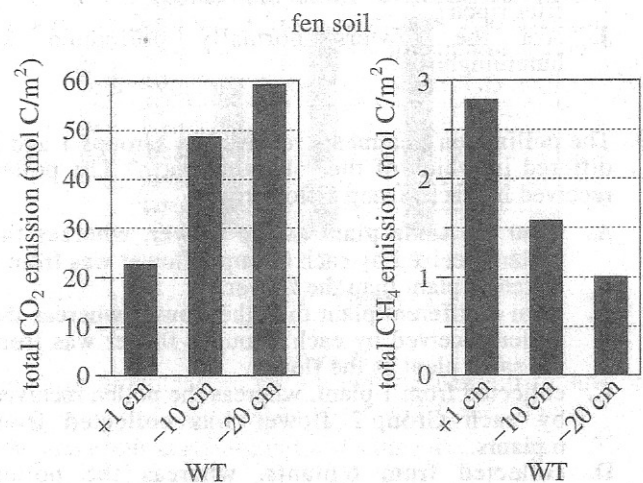


Figure 2

Figures adapted from Karen Updegraff et al., "Response of CO_2 and CH_4 Emissions from Peatlands to Warming and Water Table Manipulations." ©2001 by the Ecological Society of America.

14. The researchers who conducted the study most likely chose to conduct it during the summer rather than during the winter because organic matter in soil is broken down:

- F. in the summer by aerobic bacteria only and in the winter by anaerobic bacteria only.
- G. in the summer by anaerobic bacteria only and in the winter by aerobic bacteria only.
- H. by both aerobic and anaerobic bacteria more rapidly in the summer than in the winter.
- J. by both aerobic and anaerobic bacteria less rapidly in the summer than in the winter.

15. According to the results of the study, as the water table for the bog soil sections and the fen soil sections became progressively lower, did the total CO_2 emission increase or decrease, and did the total CH_4 emission increase or decrease?

	<u>total CO_2 emission</u>	<u>total CH_4 emission</u>
A.	increased	decreased
B.	decreased	increased
C.	increased	increased
D.	decreased	decreased

16. One of the reasons that the lid on each tank was kept closed for the 3-month period was to:

- F. minimize the amount of emitted gas that exited the tank.
- G. maximize the amount of atmospheric gas that entered the tank.
- H. prevent bacteria from leaving the tank.
- J. prevent sunlight from entering the tank.

17. The 2 types of wetland investigated in this study—bogs and fens—have different levels of the nutrients that sustain bacterial growth. Do the results of the study suggest that the levels of the nutrients that sustain aerobic bacteria are higher in bogs or in fens, and do the results of the study suggest that the levels of the nutrients that sustain anaerobic bacteria are higher in bogs or in fens?

	<u>higher nutrients for aerobic bacteria</u>	<u>higher nutrients for anaerobic bacteria</u>
A.	bogs	bogs
B.	bogs	fens
C.	fens	bogs
D.	fens	fens

18. Based on the results of the study for the 2 soil sections that were completely submerged in water, were aerobic bacteria present in those sections?

- F. Yes; CO_2 was emitted from those sections.
- G. Yes; CH_4 was emitted from those sections.
- H. No; only CO_2 was emitted from those sections.
- J. No; only CH_4 was emitted from those sections.

19. Consider the total CO_2 emission from the fen soil section having a WT of -10 cm. Based on that result, over the 3 months, the average CO_2 emission from that soil section *per month* would have been closest to which of the following?

- A. 10 mol C/m^2
- B. 13 mol C/m^2
- C. 16 mol C/m^2
- D. 19 mol C/m^2

20. The study was conducted at an outdoor site near the wetlands to ensure that the tanks would be nearly identical to the wetlands with respect to which of the following conditions?

- F. Amount of precipitation
- G. Types of plants present
- H. Volume of soil
- J. Hours of daylight

Passage IV

Physics students performed 3 studies to determine the forces that several doors exerted on their hinges. The doors had various weights, W , and widths, D . Each door had 2 hinges; the hinges could be moved to vary the distance, S , between them. None of the doors had a doorknob.

The 2 hinges on each door were equidistant from the center of mass of the door (see the diagram).

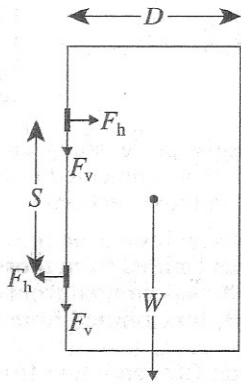


diagram of door

Each hinge was fitted with 2 force sensors. With the door attached to a door frame, one of the sensors detected the *horizontal force* exerted by the door on the hinge, F_h , and the other sensor detected the *vertical force* exerted by the door on the hinge, F_v . Once F_h and F_v were determined for each hinge, F_h was averaged over the 2 hinges, yielding the average horizontal force per hinge, $F_{h,av}$, and F_v was averaged over the 2 hinges, yielding the average vertical force per hinge, $F_{v,av}$. From $F_{h,av}$ and $F_{v,av}$, the average net force per hinge, $F_{n,av}$, could be calculated.

In the 3 studies, all forces were recorded in pounds (lb) and all lengths were recorded in inches (in).

Study 1

For a door with $W = 61$ lb and $D = 30$ in, the students determined $F_{h,av}$ and $F_{v,av}$ at various S . The results are shown in Figure 1.

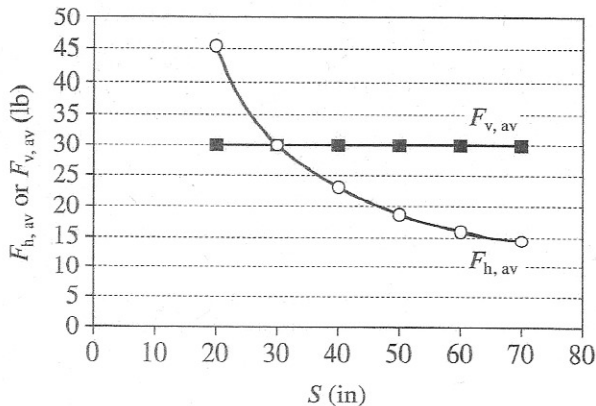


Figure 1

Study 2

For 3 doors, each with $D = 30$ in but a different W , the students determined $F_{n,av}$ at various S . The results are shown in Figure 2.

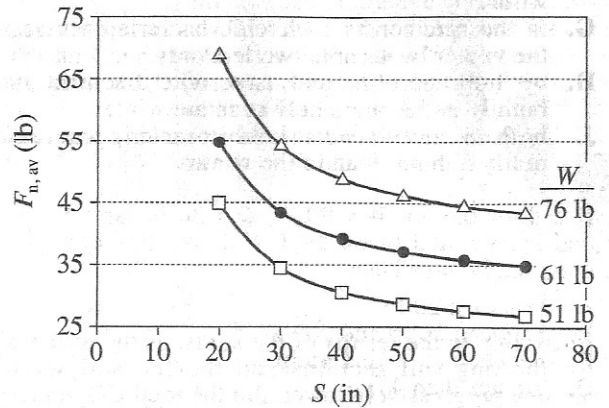


Figure 2

Study 3

For 3 doors, each with $W = 61$ lb but a different D , the students determined $F_{n,av}$ at various S . The results are shown in Figure 3.

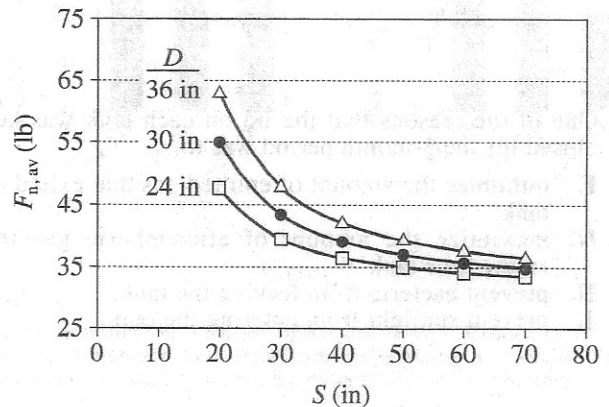


Figure 3

21. In which study, if any, was the door with the greatest mass tested?

- A. Study 1
- B. Study 2
- C. Study 3
- D. None of the studies; all the doors tested in the 3 studies had the same mass.

22. Which of the following statements regarding W and D best describes a difference between Study 2 and Study 3? In Study 2:

- F. W was varied while D was held constant, whereas in Study 3, W was held constant while D was varied.
- G. W was held constant while D was varied, whereas in Study 3, W was varied while D was held constant.
- H. both W and D were varied, whereas in Study 3, both W and D were held constant.
- J. both W and D were held constant, whereas in Study 3, both W and D were varied.

23. If a door having $W = 90$ lb, $D = 30$ in, and $S = 50$ in had been tested in Study 2, $F_{n,av}$ for this door would most likely have been:

- A. less than 20 lb.
- B. between 20 lb and 30 lb.
- C. between 30 lb and 45 lb.
- D. greater than 45 lb.

24. For the door tested in Study 1, when S was less than 30 in, was $F_{h,av}$ less than $F_{v,av}$ or greater than $F_{v,av}$, and when S was greater than 30 in, was $F_{h,av}$ less than $F_{v,av}$ or greater than $F_{v,av}$?

	<u>S less than 30 in</u>	<u>S greater than 30 in</u>
F.	less	less
G.	less	greater
H.	greater	less
J.	greater	greater

25. In Studies 2 and 3, which combination of W , D , and S resulted in the lowest $F_{n,av}$?

	<u>W (lb)</u>	<u>D (in)</u>	<u>S (in)</u>
A.	51	30	20
B.	51	30	70
C.	61	24	20
D.	61	24	70

26. In Study 1, which average force, $F_{h,av}$ or $F_{v,av}$, was independent of S ?

- F. $F_{h,av}$, because as S increased, $F_{h,av}$ decreased.
- G. $F_{h,av}$, because as S increased, $F_{h,av}$ remained constant.
- H. $F_{v,av}$, because as S increased, $F_{v,av}$ decreased.
- J. $F_{v,av}$, because as S increased, $F_{v,av}$ remained constant.

27. Suppose that, due to a manufacturing defect, a particular pair of hinges will break when a net force greater than 57 lb is exerted on each hinge. Based on Study 3, the hinges will most likely break if used on a 61 lb door with which of the following combinations of D and S ?

	<u>D (in)</u>	<u>S (in)</u>
A.	30	20
B.	30	70
C.	36	20
D.	36	70

Passage V

In a chemistry class, the teacher placed 0.5 g of porous steel wool, composed mostly of iron (Fe), inside a small heat-resistant quartz tube. She then used silicone hoses to connect the quartz tube to 2 airtight glass syringes (see figure). Each syringe contained 8 mL of air, and the total volume of air in the closed apparatus was 20 mL.

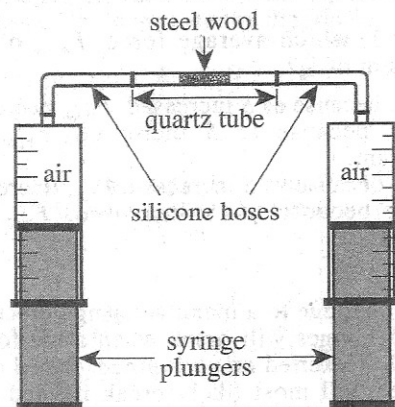


Figure adapted from Francisco Vera, Rodrigo Rivera, and César Núñez, "A Simple Experiment to Measure the Content of Oxygen in the Air Using Heated Steel Wool." ©2011 by Division of Chemical Education, Inc., American Chemical Society.

A Bunsen burner was then used to heat the contents of the quartz tube for 2 min. During heating, the plungers were moved up and down to pass the air back and forth through the steel wool. The total volume of gas in the apparatus steadily declined over the 2 min. Once the apparatus and its contents returned to room temperature, the total volume of gas in the apparatus was 16 mL.

The teacher asked each of 4 students to explain what occurred during the demonstration.

Student 1

During heating, the Fe in the steel wool reacted with all the N_2 in the air to form solid iron nitride (FeN), which was deposited on the steel wool. Air contains about 20% N_2 by volume. As a result of the reaction, the total volume of gas in the apparatus decreased by about 20%, so almost all the gas remaining in the apparatus was O_2 .

Student 2

During heating, the Fe in the steel wool reacted with some of the O_2 in the air to form solid iron oxide (Fe_2O_3), which was deposited on the steel wool. Air contains about 80% O_2 by volume. As a result of the reaction, the total volume of gas in the apparatus decreased by about 20%. Almost all the gas remaining in the apparatus was a mixture of about 75% O_2 and 25% N_2 by volume.

Student 3

Student 2 is correct, except that (1) the Fe in the steel wool reacted with all the O_2 in the air and (2) air contains about 20% O_2 by volume. After the reaction, almost all the gas remaining in the apparatus was N_2 .

Student 4

During heating, the Fe in the steel wool reacted with all the CO_2 in the air to form solid iron carbonate ($FeCO_3$), which was deposited on the steel wool. Air contains about 20% CO_2 by volume. As a result of the reaction, the total volume of gas in the apparatus decreased by about 20%, so almost all the gas remaining in the apparatus was O_2 .

28. Air contains less than 1% argon by volume. This information *weakens* the explanations given by which of the students, if any?
- Students 1 and 2 only
 - Students 3 and 4 only
 - All of the students
 - None of the students
29. Silicone hoses were most likely used to connect the quartz tube to the syringes because silicone has which of the properties listed below?
- Strong resistance to heat
 - Low chemical reactivity
 - High solubility in water
- I and II only
 - I and III only
 - II and III only
 - I, II, and III
30. Based on Student 4's explanation, during the demonstration, did the percent CO_2 by volume in the apparatus increase or decrease, and did the percent O_2 by volume in the apparatus increase or decrease?
- | | percent CO_2
by volume | percent O_2
by volume |
|----|------------------------------------|-----------------------------------|
| F. | increase | increase |
| G. | increase | decrease |
| H. | decrease | decrease |
| J. | decrease | increase |
31. Which of the students would be likely to agree that, by volume, air contains more O_2 than N_2 ?
- Students 1 and 2 only
 - Students 1 and 3 only
 - Students 1, 2, and 4 only
 - Students 1, 3, and 4 only
32. Based on Student 3's explanation, the reaction that occurred during the demonstration would be represented by which of the following balanced chemical equations?
- $2\text{Fe}_2\text{O}_3 \rightarrow 4\text{Fe} + 3\text{O}_2$
 - $2\text{FeN} \rightarrow 2\text{Fe} + \text{N}_2$
 - $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$
 - $2\text{Fe} + \text{N}_2 \rightarrow 2\text{FeN}$
33. Which of the students, if any, would be likely to agree that at the end of the demonstration, the gas remaining in the apparatus was at least 20% N_2 by volume?
- Student 2 only
 - Students 2 and 3 only
 - All of the students
 - None of the students
34. In a chemical reaction, the *limiting reactant* is the reactant that is in the shortest supply and thus limits the amount of product that can be produced. Which student would be the most likely to agree that the limiting reactant during the demonstration was the iron in the steel wool?
- Student 1
 - Student 2
 - Student 3
 - Student 4

Passage VI

Quarks constitute 1 of the 3 classes of elementary particles that form all matter in the universe. Three quarks bound together form a type of particle called a *baryon*. A quark's *effective mass* (mass when bound to other quarks) is greater than its *single-quark mass* (mass when unbound). In addition, all quarks possess a property called *spin*. A quark's spin can be oriented in 1 of 2 directions, *spin-up* (\uparrow) or *spin-down* (\downarrow).

Table 1 lists the symbol, electric charge, and approximate single-quark mass for each of the 6 quarks.

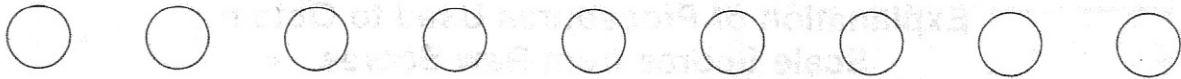
Quark	Symbol	Electric charge	Single-quark mass (MeV*)
Down	d	$-\frac{1}{3}$	5
Up	u	$+\frac{2}{3}$	3
Strange	s	$-\frac{1}{3}$	104
Charm	c	$+\frac{2}{3}$	1,270
Bottom	b	$-\frac{1}{3}$	4,200
Top	t	$+\frac{2}{3}$	171,200

*million electron volts

Table 2 gives the symbol, mass, quark content, and quark spins for several baryons.

Baryon	Symbol	Mass (MeV)	Quark content	Quark spins
Proton	p	938	uud	$\uparrow\downarrow\uparrow$
Neutron	n	939	udd	$\uparrow\downarrow\uparrow$
Lambda-zero	Λ^0	1,115	uds	$\uparrow\downarrow\uparrow$
Delta-zero	Δ^0	1,233	udd	$\uparrow\uparrow\uparrow$
Delta-minus	Δ^-	1,234	ddd	$\uparrow\uparrow\uparrow$
Omega-minus	Ω^-	1,673	sss	$\uparrow\uparrow\uparrow$

Tables adapted from C. Amsler et al., "Review of Particle Physics." ©2008 by Elsevier B.V.

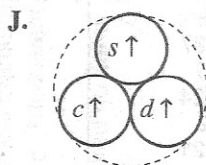
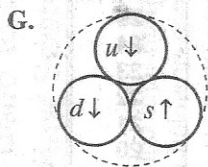
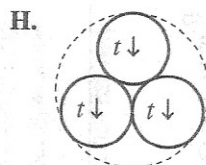
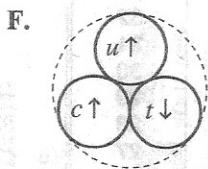


35. For all quarks, the amount of spin is always $\frac{1}{2}\hbar$, where \hbar is a constant. A spin-up quark has spin $+\frac{1}{2}\hbar$, and a spin-down quark has spin $-\frac{1}{2}\hbar$. Given that the spin of a baryon equals the sum of its quark spins, what are the spins of the Λ^0 and Δ^0 baryons listed in Table 2?

$$\Lambda^0 \quad \Delta^0$$

- A. $-\frac{1}{2}\hbar \quad -\frac{3}{2}\hbar$
 B. $-\frac{1}{2}\hbar \quad -\frac{1}{2}\hbar$
 C. $+\frac{1}{2}\hbar \quad +\frac{3}{2}\hbar$
 D. $+\frac{3}{2}\hbar \quad +\frac{3}{2}\hbar$

36. Which of the following diagrams represents the quark content and quark spins for an electrically neutral baryon having only 2 quark spins oriented in the same direction?



37. Is the information in Tables 1 and 2 consistent with the known electric charge for the proton?
- A. No, because Tables 1 and 2 indicate the proton has an electric charge of 0.
 B. No, because Tables 1 and 2 indicate the proton has an electric charge of +1.
 C. Yes, because Tables 1 and 2 indicate the proton has an electric charge of 0.
 D. Yes, because Tables 1 and 2 indicate the proton has an electric charge of +1.
38. Based on Tables 1 and 2, the Ω^- baryon has the same electric charge as a baryon containing which of the following quark combinations?
- F. *dsb*
 G. *ssc*
 H. *sst*
 J. *usc*
39. Based on Tables 1 and 2, atomic nuclei are made up of which types of quarks?
- A. *u* and *d* only
 B. *d* and *s* only
 C. *u* and *s* only
 D. *u*, *d*, and *s* only
40. The 6 quarks are grouped into 3 generations as shown in the table below.

Generation	Quarks
1	<i>d, u</i>
2	<i>s, c</i>
3	<i>b, t</i>

For which generation, if any, is the statement "Positively charged quarks are more massive than negatively charged quarks" NOT true?

- F. Generation 1
 G. Generation 2
 H. Generation 3
 J. None of the generations; the statement is true for all 3 generations.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.