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

Fin whales engulf and filter massive amounts of water and prey during an event called *lunge feeding*. The 5 distinct stages of a lunge-feeding event are listed and described below.

- Stage 1: Rapid acceleration of the whale
- Stage 2: Mouth opening and engulfment
- Stage 3: Onset of mouth closure
- Stage 4: Continued mouth closure and pre-purging
- Stage 5: Purging (filtering water from prey)

The figure below shows how a fin whale's speed and *gape angle* (angle between the top and the bottom of the fin whale's mouth) varied during a lunge-feeding event.

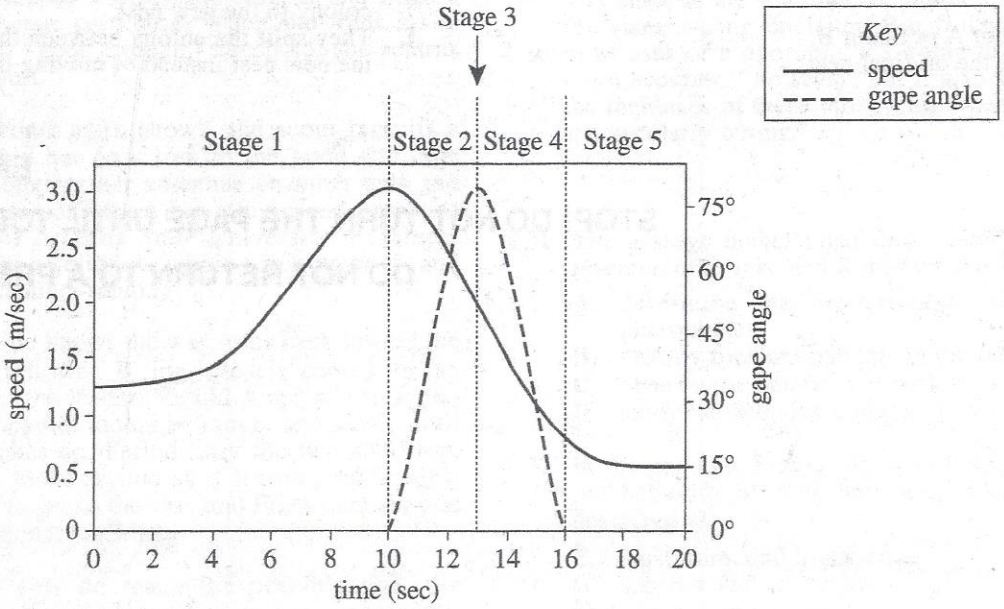


Figure adapted from J. Potvin et al., "Passive Versus Active Engulfment: Verdict from Trajectory Simulations of Lunge-Feeding Fin Whales *Balaenoptera physalus*." ©2009 by The Royal Society.

1. Over which of the following time periods of the lunge-feeding event did the gape angle both increase and decrease?

   A. 0–6 sec
   B. 8–12 sec
   C. 12–14 sec
   D. 14–18 sec

2. The figure indicates that at Stage 3 of the lunge-feeding event, the fin whale was:

   F. moving at its greatest speed and had just opened its mouth to begin engulfment.
   G. moving at its greatest speed and had just closed its mouth to begin purging.
   H. slowing down, and the whale's gape angle was at its greatest value.
   J. speeding up, and the whale's gape angle was at its smallest value.

3. What was the fin whale's gape angle 6 sec into the lunge-feeding event?

   A. 0°
   B. 15°
   C. 45°
   D. 75°

4. During the lunge-feeding event, how much time elapsed from the start of mouth opening to the end of mouth closure?

   F. 6 sec
   G. 10 sec
   H. 16 sec
   J. 20 sec

5. Among the following times during Stage 1 of the lunge-feeding event, at which time did the fin whale have the greatest amount of momentum?

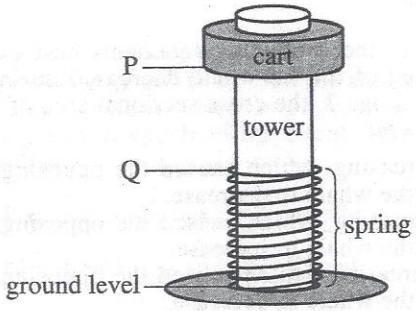
   A. 2 sec
   B. 4 sec
   C. 6 sec
   D. 8 sec

6. Which of the following statements best explains why the speed of the fin whale decreased during Stage 2 ? During Stage 2, the cross-sectional area of the whale's mouth was:

   F. increasing, which caused the opposing drag force on the whale to decrease.
   G. increasing, which caused the opposing drag force on the whale to increase.
   H. decreasing, which caused the opposing drag force on the whale to decrease.
   J. decreasing, which caused the opposing drag force on the whale to increase.

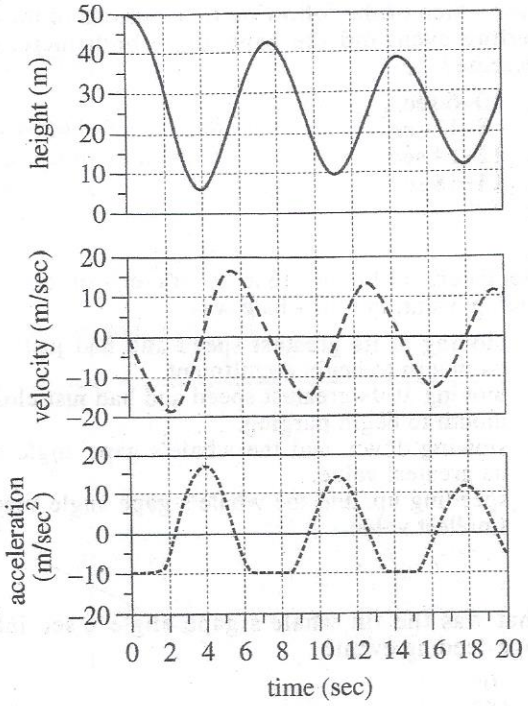
Passage II

Figure 1 shows a model of an amusement park ride. At time = 0 sec, the cart is released from rest at Point P. It descends the tower toward Point Q and strikes the spring. As the spring is compressed, it slows the cart's descent and eventually rebounds, sending the cart back up the tower. Frictional forces act on the cart whenever it is in motion, and the spring never extends above Point Q. Figure 2 shows computer simulations of the cart's height (the distance from ground level to the bottom of the cart), its velocity, and its acceleration during the first 20 sec of motion.



Note: Figure is not drawn to scale.

Figure 1



Note: Downward velocities and accelerations are graphed as negative values.

Figure 2

7. At approximately what time(s) during the 20 sec period, if any, does the cart touch the ground?

   A. 4 sec only
   B. 4 sec and 11 sec only
   C. 4 sec, 11 sec, and 18 sec only
   D. At no time does the cart touch the ground.

8. The cart's greatest upward acceleration has approximately what value and occurs at approximately what time?

	acceleration (m/sec^2)	time (sec)
F.	13	0
G.	13	4
H.	17	0
J.	17	4

9. The maximum height the cart reaches on its third trip up the tower is most likely:

   A. less than 20 m.
   B. between 20 m and 30 m.
   C. between 30 m and 40 m.
   D. greater than 40 m.

10. At time = 16 sec, what are the approximate values of the cart's height, velocity, and acceleration?

	height (m)	velocity (m/sec)	acceleration (m/sec^2)
F.	29	−11	−2.5
G.	29	−9	2.5
H.	31	−11	−2.5
J.	31	−9	2.5

11. At time = 7 sec, the bottom of the cart is approximately how far above or below Point P ?

    A. 10 m above
    B. 40 m above
    C. 10 m below
    D. 40 m below

12. The gravitational potential energy of the cart is greatest at approximately what time during the 20 sec period?

    F. 0 sec
    G. 4 sec
    H. 11 sec
    J. 14 sec

Passage III

Southern pine beetles (SPBs) construct nursery galleries for their larvae within the bark of pine trees. SPBs introduce Fungus M into the nursery gallery to serve as a food source for developing SPB larvae. If a competitor fungus—Fungus A—outcompetes Fungus M in the gallery, SPB larval development will be disrupted.

SPBs also introduce into the nursery gallery a bacterial species that is thought to help maintain the relationship between SPBs and Fungus M. Two strains of this bacterial species, Strain W and Strain R, have been isolated from SPBs. Scientists did 2 experiments to study whether the introduction of Strain W or Strain R would be more likely to protect the larval food supply.

Experiment 1

An agar growth medium contained in each of 160 petri dishes was inoculated at its center with Strain W. The medium in each dish was also inoculated, at a point near its edge, with a fungal species: in 80 dishes with Fungus M and in the other 80 dishes with Fungus A. At the end of 6 weeks, the shortest distance across the *zone of inhibition* (ZOI; the space between the edges of fungal growth and of bacterial growth) was measured for each dish. The shortest distance for a dish, defined here as the width of the ZOI, determined the *degree of inhibition* exhibited by the dish (see Table 1).

Table 1

Width of ZOI (cm)	Degree of inhibition
< 0.5	little or none
0.5–2.5	mild
> 2.5	strong

Figure 1 shows, for each fungus, what percent of the 80 dishes exhibited a given degree of inhibition.

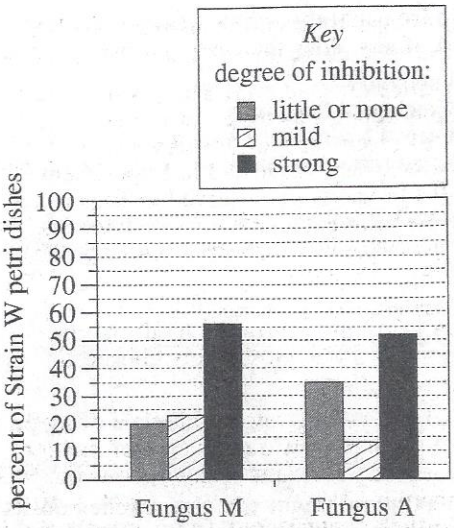


Figure 1

Experiment 2

Experiment 1 was repeated, except with Strain R instead of Strain W (see Figure 2).

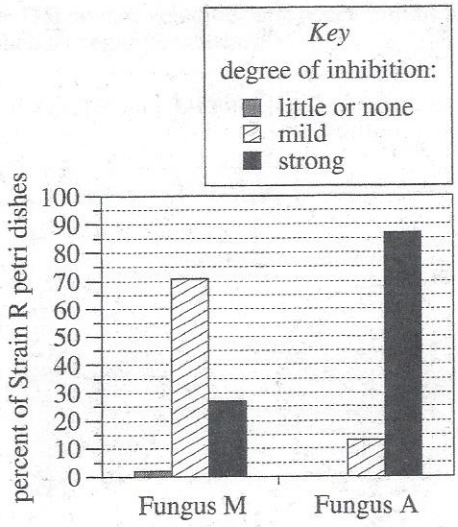


Figure 2

Table and figures adapted from Jarrod J. Scott et al., "Bacterial Protection of Beetle-Fungus Mutualism." ©2008 by American Association for the Advancement of Science.

13. Which of the following statements describes a difference between Experiments 1 and 2 ?

A. A different bacterial strain was tested in Experiment 1 than was tested in Experiment 2.
B. A different fungal species was tested in Experiment 1 than was tested in Experiment 2.
C. SPB larvae were observed in Experiment 1 but not in Experiment 2.
D. SPB larvae were observed in Experiment 2 but not in Experiment 1.

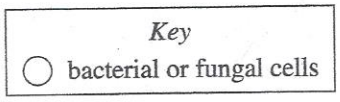
14. The type of agar growth medium used in Experiments 1 and 2 was most likely chosen for which of the following reasons?

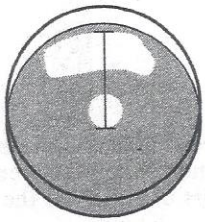
F. Only bacteria grow on this type of medium.
G. Only fungi grow on this type of medium.
H. Both bacteria and fungi grow on this type of medium.
J. Neither bacteria nor fungi grow on this type of medium.

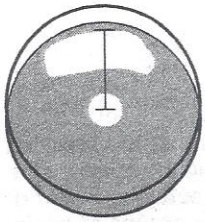
15. Consider the petri dishes containing Strain R and Fungus M. What percent of those dishes exhibited a mild degree of inhibition?

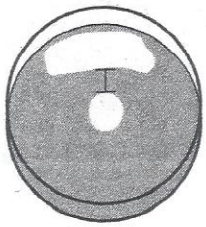
A. 2%
B. 13%
C. 23%
D. 71%

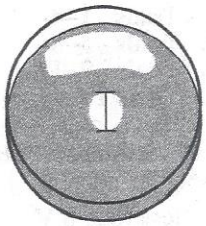
16. The width of a ZOI is best depicted by which of the following figures?



F.


H.


G.


J.


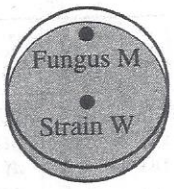
17. The width of the ZOI for more than half of the petri dishes containing Strain W and Fungus M was within what range?

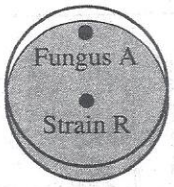
A. < 0.5 cm
B. 0.5 cm–2.5 cm
C. > 2.5 cm
D. Cannot be determined from the given information

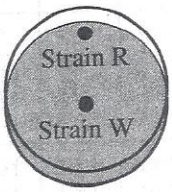
18. Based on the results of Experiment 2, the introduction of Strain R into a nursery gallery by SPBs would more likely strongly inhibit the growth of which fungus, Fungus M or Fungus A ?

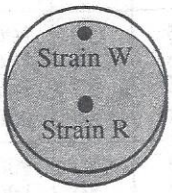
F. Fungus M, because approximately 27% of the petri dishes containing Strain R and Fungus M exhibited a strong degree of inhibition.
G. Fungus M, because approximately 71% of the petri dishes containing Strain R and Fungus M exhibited a strong degree of inhibition.
H. Fungus A, because approximately 52% of the petri dishes containing Strain R and Fungus A exhibited a strong degree of inhibition.
J. Fungus A, because approximately 87% of the petri dishes containing Strain R and Fungus A exhibited a strong degree of inhibition.

19. Which of the following figures best depicts each of 80 of the petri dishes in Experiment 1 immediately following inoculation?

A.


C.


B.


D.


Passage IV

A *transformer* is an electrical component used to increase or decrease voltage. In 3 experiments, a group of students studied transformers using the setup shown in Figure 1.

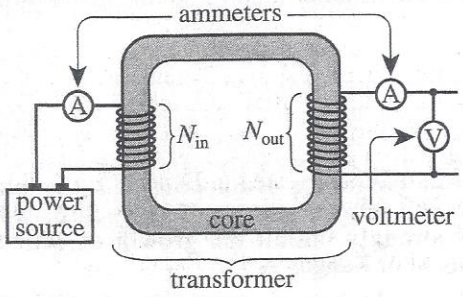


Figure 1

An input coil was wrapped N_{in} turns around one side of a *core* (a solid ring) and then connected to an *ammeter* (current-measuring device) and a power source. An output coil was wrapped N_{out} turns around the opposite side of the core and then connected to an ammeter and a voltmeter. $\mathscr{E}_{in}$ and $\mathscr{E}_{out}$ were the input and output voltages (in volts, V), respectively. I_{in} and I_{out} were the input and output currents (in milliamperes, mA), respectively.

Experiment 1

In Trials 1–12, the core was made of iron, and the power source was a generator of *alternating current* (AC; current that varies over time). The students measured I_{in}, $\mathscr{E}_{out}$, and I_{out} for various combinations of N_{in}, N_{out}, and $\mathscr{E}_{in}$ (see Table 1).

Table 1

Trial	N_{in}	N_{out}	$\mathscr{E}_{in}$ (V)	I_{in} (mA)	$\mathscr{E}_{out}$ (V)	I_{out} (mA)
1	100	50	30	100	15	200
2	150	50	30	100	10	300
3	200	50	30	100	8	400
4	250	50	30	100	6	500
5	50	100	30	100	60	50
6	50	150	30	100	90	33
7	50	200	30	100	120	25
8	50	250	30	100	150	20
9	50	100	60	200	120	100
10	50	100	90	300	180	150
11	50	100	120	400	240	200
12	50	100	150	500	300	250

Experiment 2

In Trials 13–17, the procedure followed in Trial 5 was repeated except that the core material was varied (see Table 2).

Table 2

Trial	Core material	I_{in} (mA)	$\mathscr{E}_{out}$ (V)	I_{out} (mA)
13	aluminum	100	0	0
14	cobalt	100	61	49
15	glass	100	0	0
16	nickel	100	59	50
17	vinyl	100	0	0

Experiment 3

The procedures followed in Trials 1–12 were repeated, except that the power source was a battery supplying *direct current* (DC; current that remains constant over time). The I_{in} results matched those of Experiment 1, but in every trial, $\mathscr{E}_{out}$ was 0 V and I_{out} was 0 mA.

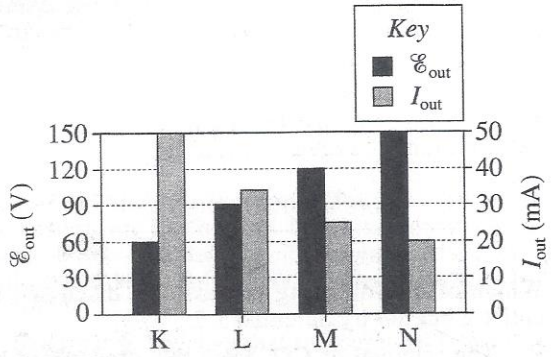
20. One of the students concluded that as $\mathscr{E}_{in}$ increases, I_{in} also increases. The student most likely arrived at this conclusion based on the results of which of the following groups of trials?

F. Trials 1–4
G. Trials 5–8
H. Trials 9–12
J. Trials 13–17

21. If N_{in} had been 300 turns in Trial 4, $\mathscr{E}_{out}$ would most likely have been:

A. less than 6 V.
B. between 6 V and 8 V.
C. between 8 V and 10 V.
D. greater than 10 V.

22. Consider the figure below, which shows values of $\mathscr{E}_{out}$ and I_{out} for Trials K, L, M, and N.



Based on the results of Experiments 1 and 2, Trials K, L, M, and N correspond to, respectively:

F. Trials 1, 2, 3, and 4.
G. Trials 5, 6, 7, and 8.
H. Trials 9, 10, 11, and 12.
J. Trials 13, 14, 15, and 16.

23. Suppose that a trial were performed in which $N_{in} = 50$ turns, $N_{out} = 300$ turns, and $\mathscr{E}_{in} = 30$ V AC. If the core were made of iron, which of the following combinations of I_{in}, $\mathscr{E}_{out}$, and I_{out} would most likely result from this trial?

	I_{in} (mA)	$\mathscr{E}_{out}$ (V)	I_{out} (mA)
A.	100	10	300
B.	100	180	17
C.	200	10	250
D.	200	180	7

24. For a transformer like those tested in Experiments 1–3 to generate an output voltage, a phenomenon called *induction* must occur in the core. Based on the results of Experiments 1 and 3, induction occurred only in the trials with:

F. an AC power source, because the transformers tested in Experiment 1 generated an output voltage, but those tested in Experiment 3 did not.
G. an AC power source, because the transformers tested in Experiment 3 generated an output voltage, but those tested in Experiment 1 did not.
H. a DC power source, because the transformers tested in Experiment 1 generated an output voltage, but those tested in Experiment 3 did not.
J. a DC power source, because the transformers tested in Experiment 3 generated an output voltage, but those tested in Experiment 1 did not.

25. In Experiments 1–3, there was *no* trial performed with a:

A. metal core and an AC power supply.
B. metal core and a DC power supply.
C. nonmetal core and an AC power supply.
D. nonmetal core and a DC power supply.

26. In Trials 13–17, the values of N_{in}, N_{out}, and $\mathscr{E}_{in}$ were, respectively:

F. 50 turns, 100 turns, and 30 V.
G. 50 turns, 100 turns, and 60 V.
H. 100 turns, 50 turns, and 30 V.
J. 100 turns, 50 turns, and 60 V.

Passage V

Two scientists discuss whether a *snowball Earth* (Earth completely covered with glacial ice) existed from 710 million years ago (mya) to 700 mya, a period during which all the continents were located on or near the equator.

Scientist 1

A million years before 710 mya, glacial ice covered all of Earth's surface except the *low latitudes* (30°N to 30°S). Over the next million years, continuing rapid rock weathering in the low latitudes removed CO_2 from the atmosphere, and the ice at high latitudes reflected incoming solar radiation. Both processes cooled Earth, which allowed the ice to spread and cover the remainder of Earth's surface by 710 mya. Soon thereafter, the 1-kilometer-thick ice cover caused the extinction of all photosynthetic organisms. Sediments deposited at the low latitudes by glaciers during the period from 710 mya to 700 mya have been found.

Banded iron formations (BIFs) that formed in the 1 million years after 700 mya at the low latitudes have been found. The BIFs formed only in ocean water that was saturated with Fe^{2+}, an ion of iron that reacts readily with atmospheric O_2. Saturation with Fe^{2+} was possible only if an ocean had been cut off from atmospheric O_2 for millions of years by thick ice. Once the ice melted, the Fe^{2+} reacted with O_2 to form BIFs.

Scientist 2

From 710 mya to 700 mya, glacial ice covered all of Earth's surface except the low latitudes. The low latitudes remained mostly ice-free over this period because the continents there absorbed enough solar radiation to keep the average temperature above 0°C. Although rapid rock weathering was removing CO_2 from the atmosphere, widespread, continual volcanic eruptions at low latitudes simultaneously added an equal amount of CO_2 to the atmosphere.

Fossils of photosynthetic organisms from this period have been found. Some of the sediments from this period were deposited at low latitudes when floating icebergs that broke off of glaciers at high latitudes melted and dropped sediment that had been trapped in the ice. BIFs did form as described by Scientist 1, but only in the few isolated ocean basins at low latitudes that had been completely covered with thick ice over this period.

27. BIFs are composed primarily of the mineral *hematite* (Fe_2O_3). Based on Scientist 1's discussion of the formation of BIFs, which of the following expressions best represents the formation of the hematite in BIFs ?

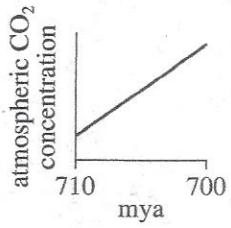
A. oxygen → iron ion + hematite
B. hematite + iron ion → oxygen
C. iron ion → hematite + oxygen
D. iron ion + oxygen → hematite

28. Which of the following processes is discussed by Scientist 2 but not by Scientist 1 ?

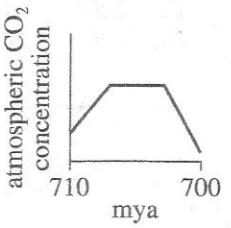
F. The removal of CO_2 from the atmosphere by rock weathering
G. The addition of CO_2 to the atmosphere by volcanoes
H. The extinction of photosynthetic organisms
J. The formation of BIFs

29. Assume that from 710 mya to 700 mya, rock weathering was the only process removing CO_2 from the atmosphere and volcanic eruption was the only process adding CO_2 to the atmosphere. Based on Scientist 2's discussion, which of the following graphs best represents the CO_2 concentration in the atmosphere over this period?

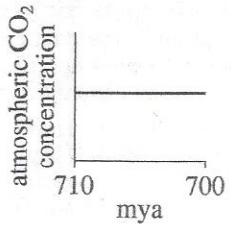
A.



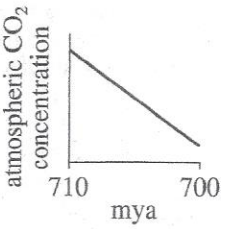
C.



B.



D.



30. Fossils of the photosynthetic organisms mentioned by Scientist 2 would most likely have been found from 710 mya to 700 mya in areas at which of the following latitudes?

F. 60°N
G. 40°N
H. 20°S
J. 50°S

31. Suppose it were discovered that air temperatures everywhere on Earth were continuously at or below −10°C from 710 mya to 700 mya. This discovery would more strongly support the viewpoint of which scientist?

A. Scientist 1, because that temperature is well above the maximum temperature at which glacial ice can form.
B. Scientist 1, because that temperature is well below the maximum temperature at which glacial ice can form.
C. Scientist 2, because that temperature is well above the maximum temperature at which glacial ice can form.
D. Scientist 2, because that temperature is well below the maximum temperature at which glacial ice can form.

32. Suppose it were discovered that no O_2 had been present in Earth's atmosphere from 700 mya to 690 mya. Would the viewpoint of Scientist 1 be strengthened or weakened by this discovery?

F. Strengthened, because it would indicate that BIFs would have formed at low latitudes during that period.
G. Strengthened, because it would indicate that BIFs would not have formed at low latitudes during that period.
H. Weakened, because it would indicate that BIFs would have formed at low latitudes during that period.
J. Weakened, because it would indicate that BIFs would not have formed at low latitudes during that period.

33. Suppose it were discovered that most of Earth's surface between 30°N and 60°N latitude was ice-free 705 mya. This discovery would *contradict* one or more statements made by which of the scientists, if either?

A. Scientist 1 only
B. Scientist 2 only
C. Both scientists
D. Neither scientist

Passage VI

The *ideal gas law* (IGL) describes the physical behavior of gases. Although ideal gases do not exist, the IGL is a useful model for many real gases. A researcher used the IGL to predict trends in the pressure of an ideal gas under various sets of conditions. Then, the researcher performed 3 experiments to compare the IGL predictions with trends in the pressure of each of 2 real gases (Gas Y and Gas Z) under the same sets of conditions. The conditions that were varied for an ideal gas, for Gas Y, and for Gas Z were the following:

- The gas temperature, T (in kelvins, K)
- The amount of gas, n (in *moles*, mol; 1 mol = 6.0×10^{23} atoms or molecules), in a container
- The volume of the container, V (in liters, L)

Experiment 1

The pressure, P (in megapascals, MPa), of an $n = 1$ mol sample of Gas Y in a 1.0 L container was recorded for values of T from 200 K to 450 K. This procedure was repeated for Gas Z. Figure 1 shows the trends for the 2 gases. Also shown is the trend predicted by the IGL.

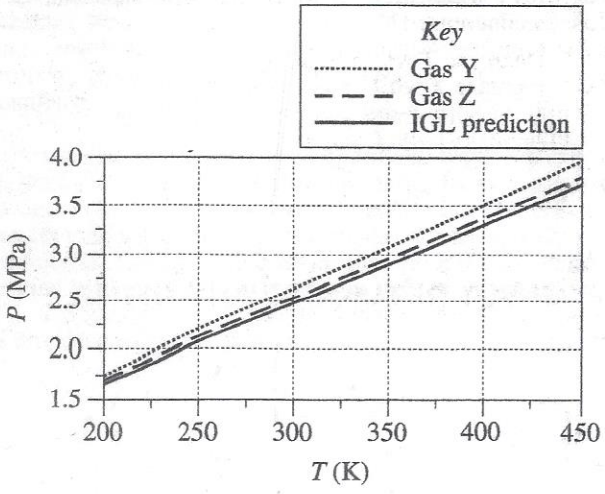


Figure 1

Experiment 2

The pressure, P, of a sample of Gas Y in a 1.0 L container was recorded for values of n from 1 mol to 10 mol, while T was held constant at 400 K. This procedure was repeated for Gas Z. Figure 2 shows the trends for the 2 gases and the trend predicted by the IGL.

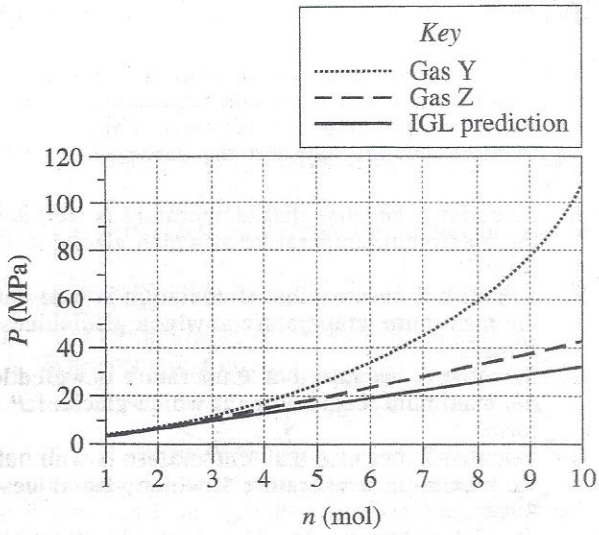


Figure 2

Experiment 3

The pressure, P, of an $n = 1$ mol sample of Gas Y in a container of adjustable volume was recorded for values of V from 0.5 L to 1.0 L, while T was held constant at 400 K. This procedure was repeated for Gas Z. Figure 3 shows the trends for the 2 gases and the trend predicted by the IGL.

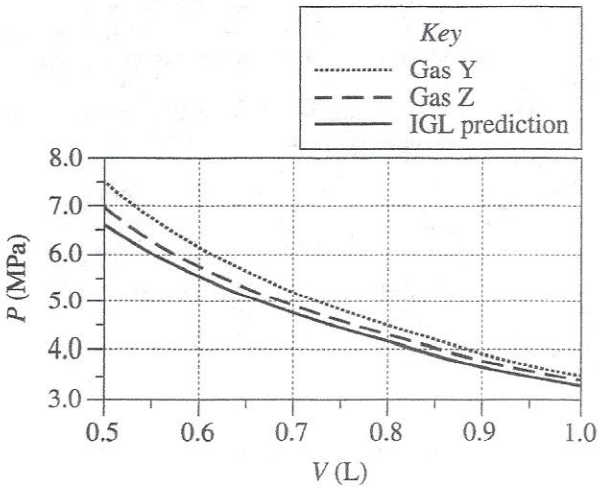


Figure 3

34. In which experiments was T held constant?

F. Experiments 1 and 2 only
G. Experiments 1 and 3 only
H. Experiments 2 and 3 only
J. Experiments 1, 2, and 3

35. The purpose of Experiment 2 was most likely to determine the relationship between:

A. P and T while holding n and V constant.
B. P and n while holding T and V constant.
C. n and T while holding V and P constant.
D. n and V while holding P and T constant.

36. Based on the results of Experiments 1–3, which gas exhibited behaviors more like those that were predicted by the IGL ?

F. Gas Y, because values of P for Gas Y deviated more from the IGL predictions than did values of P for Gas Z.
G. Gas Y, because values of P for Gas Y deviated less from the IGL predictions than did values of P for Gas Z.
H. Gas Z, because values of P for Gas Z deviated more from the IGL predictions than did values of P for Gas Y.
J. Gas Z, because values of P for Gas Z deviated less from the IGL predictions than did values of P for Gas Y.

37. In Experiment 1, was the average kinetic energy of Gas Y molecules more likely greater at $P = 2.0$ MPa or at $P = 4.0$ MPa ?

A. At $P = 2.0$ MPa, because at that lower pressure, the gas molecules had less room in which to move.
B. At $P = 2.0$ MPa, because the average kinetic energy of a gas increases as T decreases.
C. At $P = 4.0$ MPa, because at that higher pressure, the gas molecules had more room in which to move.
D. At $P = 4.0$ MPa, because the average kinetic energy of a gas increases as T increases.

38. The containers used in Experiments 1–3 could withstand the same maximum pressure. Based on the results of the experiments, that maximum pressure must have been closest to which of the following?

F. 4.0 MPa
G. 7.5 MPa
H. 45 MPa
J. 100 MPa

39. One mole of Gas Y has a mass of 20 g. In Experiment 2, what was the mass of the Gas Y sample when the pressure of the sample was 25 MPa ?

A. 4 g
B. 5 g
C. 100 g
D. 125 g

40. Consider an $n = 1$ mol sample of Gas Z at 400 K in a 1.0 L container of adjustable volume. Suppose the researcher must decrease the container's volume, but wishes to hold P constant. Based on the results of Experiments 1–3, which of the following additional actions should the researcher perform simultaneously as V is decreased?

F. Decrease T while holding n constant
G. Increase T while holding n constant
H. Hold both T and n constant
J. Increase both T and n

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.