Questions 14–26

The Coriolis Force

In the early part of the twentieth century, the Norwegian scientist and polar explorer Fridtjof Nansen noted that icebergs did not follow the path of the wind as common sense had assumed. Instead they tended to move to the right side of the direction in which the wind blew. A student of Nansen's, V. W. Ekman, showed that the rotation of the Earth leading to an inertial force known as the Coriolis force was responsible for this phenomenon. He further demonstrated that in the Northern Hemisphere the deflection was toward the right of the prevailing wind, and in the Southern Hemisphere the deflection was toward the left. The icebergs observed by Nansen were moved by ocean currents that also moved at an angle to the prevailing wind.

The Coriolis force itself is caused by the fact that the Earth rotates on its axis once per day, and hence all points on the planet have the same rotational velocity; that is, they take one whole day to complete a rotational circle. However, since a complete rotation around the Earth is shorter the further one is away from the equator, different points on the Earth travel at different speeds depending on degree of latitude. For example, a point on the equator travels the whole distance around the sphere (about 40,000 kilometers), whereas a point near the poles will travel a much shorter distance. Therefore, we can say that the linear speed of a point depends on its latitude above or below the equator. Thus the actual linear speed of a point on the surface is faster the nearer that point is to the equator.

Now if an untethered object (or current) is moving northward away from the equator in the Northern Hemisphere, it will also maintain the initial speed imparted to it by the eastward rotation of the Earth. That eastward deflection is faster at the equator than at more northerly (or southerly) latitudes, and thus, when the object reaches a more northerly point, it will be traveling faster in an eastward direction than the surrounding ground or water. The moving object will appear to be forced away from its path by some mysterious phenomenon. In reality the ground is simply moving at a different speed from the original speed at the object's (or current's) home position. The resulting direction of movement will therefore be at an angle of about 45 degrees to the original direction, so an object traveling north will move to the right in the Northern Hemisphere and to the left in the Southern Hemisphere with respect to the rotating Earth. An object traveling south will be deflected to the left in the Northern Hemisphere and to the right in the Southern Hemisphere.

As the surface water in the ocean is moved by the wind, it tends to veer* off at an angle of 45 degrees to the right or left. This movement exerts a drag on the water immediately below it, and the Coriolis force causes this layer to move and also to deflect to the right or left. This layer in turn drags the layer below, which in turn is deflected. At successively deeper layers, the water is deflected in relation to the layer above until at a depth of around 150 meters, the water is moving in a direction opposite to the surface water. At successively greater depths, the frictional forces between layers reduce the energy of the flow, causing water to move more slowly the deeper the layer. The resulting deflections produce a spiral pattern known as the Ekman spiral. The net movement of water is roughly at 90 degrees from the wind direction and is known as Ekman transport.

This phenomenon is an important factor in the movement of water in the oceans. Among other things, it creates zones of upwelling by forcing surface waters apart and other zones of downwelling by forcing surface waters together. For example, wind blowing parallel to the shore may create a net movement of water at 90 degrees away from the shore. Nutrient-rich deeper ocean water will upwell to take the place of the displaced water and thus profoundly influence the marine ecosystem.

***veer:** to suddenly change direction

14. The phrase "path of the wind" in the passage is closest in meaning to

(A) wind strength
(B) wind variation
(C) wind direction
(D) wind phenomenon

In the early part of the twentieth century, the Norwegian scientist and polar explorer Fridtjof Nansen noted that icebergs did not follow the path of the wind as common sense had assumed. Instead they tended to move to the right side of the direction in which the wind blew. A student of Nansen's, V. W. Ekman, showed that the rotation of the Earth leading to an inertial force known as the Coriolis force was responsible for this phenomenon. He further demonstrated that in the Northern Hemisphere the deflection was toward the right of the prevailing wind, and in the Southern Hemisphere the deflection was toward the left. The icebergs observed by Nansen were moved by ocean currents that also moved at an angle to the prevailing wind.

15. The phrase "this phenomenon" in the passage refers to

(A) the movement of icebergs
(B) the rotation of the Earth
(C) the direction of the wind
(D) the inertial Coriolis force

In the early part of the twentieth century, the Norwegian scientist and polar explorer Fridtjof Nansen noted that icebergs did not follow the path of the wind as common sense had assumed. Instead they tended to move to the right side of the direction in which the wind blew. A student of Nansen's, V. W. Ekman, showed that the rotation of the Earth leading to an inertial force known as the Coriolis force was responsible for this phenomenon. He further demonstrated that in the Northern Hemisphere the deflection was toward the right of the prevailing wind, and in the Southern Hemisphere the deflection was toward the left. The icebergs observed by Nansen were moved by ocean currents that also moved at an angle to the prevailing wind.

16. The word "rotates" in the passage is closest in meaning to

(A) spins
(B) travels
(C) twirls
(D) swivels

The Coriolis force itself is caused by the fact that the Earth rotates on its axis once per day, and hence all points on the planet have the same rotational velocity; that is, they take one whole day to complete a rotational circle. However, since a complete rotation around the Earth is shorter the further one is away from the equator, different points on the Earth travel at different speeds depending on degree of latitude. For example, a point on the equator travels the whole distance around the sphere (about 40,000 kilometers), whereas a point near the poles will travel a much shorter distance. Therefore, we can say that the linear speed of a point depends on its latitude above or below the equator. Thus the actual linear speed of a point on the surface is faster the nearer that point is to the equator.

17. We can infer that rotational velocity is

(A) the same as speed in kph
(B) different at different latitudes
(C) the same at different latitudes
(D) dependent on latitude

[Refer to the full passage.]

18. In paragraph 2, the author explains the differences in linear speed by

(A) arguing that an object moving north moves faster
(B) describing the linear velocity of the Earth
(C) identifying the eastward deflection of a current
(D) relating speed to the distance of a point from the equator

Paragraph 2 is marked with an arrow [➡].

➡ The Coriolis force itself is caused by the fact that the Earth rotates on its axis once per day, and hence all points on the planet have the same rotational velocity; that is, they take one whole day to complete a rotational circle. However, since a complete rotation around the Earth is shorter the further one is away from the equator, different points on the Earth travel at different speeds depending on degree of latitude. For example, a point on the equator travels the whole distance around the sphere (about 40,000 kilometers), whereas a point near the poles will travel a much shorter distance. Therefore, we can say that the linear speed of a point depends on its latitude above or below the equator. Thus the actual linear speed of a point on the surface is faster the nearer that point is to the equator.

19. According to the passage, a point near the equator in the Northern Hemisphere travels

(A) at the same speed as any other point
(B) faster than a point at a higher latitude
(C) slower than a point in the Southern Hemisphere
(D) at different speeds in different seasons

[Refer to the full passage.]

20. Look at the four squares [■] that indicate where the following sentence could be added to the passage.

And conversely, if the object is traveling southward toward the equator, it will be moving more slowly than the surrounding land or water.

Where would the sentence best fit?

Choose the letter of the square that shows where the sentence should be added.

Now if an untethered object (or current) is moving northward away from the equator in the Northern Hemisphere, it will also maintain the initial speed imparted to it by the eastward rotation of the Earth. A That eastward deflection is faster at the equator than at more northerly (or southerly) latitudes, and thus, when the object reaches a more northerly point, it will be traveling faster in an eastward direction than the surrounding ground or water. B The moving object will appear to be forced away from its path by some mysterious phenomenon. In reality the ground is simply moving at a different speed from the original speed at the object's (or current's) home position. C The resulting direction of movement will therefore be at an angle of about 45 degrees to the original direction, so an object traveling north will move to the right in the Northern Hemisphere and to the left in the Southern Hemisphere with respect to the rotating Earth. D An object traveling south will be deflected to the left in the Northern Hemisphere and to the right in the Southern Hemisphere.

21. According to paragraph 4, where does water move in a direction contrary to surface layers of water?

(A) Directly below the surface
(B) At 90 degrees to the surface
(C) At all depths below the surface
(D) At 150 meters below the surface

Paragraph 4 is marked with an arrow [➡].

➡ As the surface water in the ocean is moved by the wind, it tends to veer off at an angle of 45 degrees to the right or left. This movement exerts a drag on the water immediately below it, and the Coriolis force causes this layer to move and also to deflect to the right or left. This layer in turn drags the layer below, which in turn is deflected. At successively deeper layers, the water is deflected in relation to the layer above until at a depth of around 150 meters, the water is moving in a direction opposite to the surface water. At successively greater depths, the frictional forces between layers reduce the energy of the flow, causing water to move more slowly the deeper the layer. The resulting deflections produce a spiral pattern known as the Ekman spiral. The net movement of water is roughly at 90 degrees from the wind direction and is known as Ekman transport.

22. In paragraph 4, why does the author explain that the wind tends to deflect the water to the right or left?

(A) To explain the concept of upwelling
(B) To demonstrate the effect of the Coriolis force
(C) To point out causes of rotational velocity
(D) To introduce the movement of ocean currents

Paragraph 4 is marked with an arrow [➡].

➡ As the surface water in the ocean is moved by the wind, it tends to veer off at an angle of 45 degrees to the right or left. This movement exerts a drag on the water immediately below it, and the Coriolis force causes this layer to move and also to deflect to the right or left. This layer in turn drags the layer below, which in turn is deflected. At successively deeper layers, the water is deflected in relation to the layer above until at a depth of around 150 meters, the water is moving in a direction opposite to the surface water. At successively greater depths, the frictional forces between layers reduce the energy of the flow, causing water to move more slowly the deeper the layer. The resulting deflections produce a spiral pattern known as the Ekman spiral. The net movement of water is roughly at 90 degrees from the wind direction and is known as Ekman transport.

23. The word "deflected" in the passage is closest in meaning to

(A) turned
(B) pushed
(C) shoved
(D) urged

As the surface water in the ocean is moved by the wind, it tends to veer off at an angle of 45 degrees to the right or left. This movement exerts a drag on the water immediately below it, and the Coriolis force causes this layer to move and also to deflect to the right or left. This layer in turn drags the layer below, which in turn is deflected. At successively deeper layers, the water is deflected in relation to the layer above until at a depth of around 150 meters, the water is moving in a direction opposite to the surface water. At successively greater depths, the frictional forces between layers reduce the energy of the flow, causing water to move more slowly the deeper the layer. The resulting deflections produce a spiral pattern known as the Ekman spiral. The net movement of water is roughly at 90 degrees from the wind direction and is known as Ekman transport.

24. Based on the information in paragraphs 1 and 4, which of the following best explains the term "Coriolis force"?

(A) The force that creates currents
(B) The force that moves icebergs
(C) The force that opposes wind movement
(D) The force that deflects ocean water

[Refer to the full passage.]

25. According to the passage, the Ekman spiral may affect

(A) the distribution of ocean life forms
(B) the direction of the wind
(C) the speed of ocean currents
(D) the frictional forces of water layers

[Refer to the full passage.]

26. **Directions:** An introductory sentence for a brief summary of the passage is provided below. Complete the summary by selecting the THREE answer choices that express the most important ideas in the passage. Some sentences do not belong in the summary because they express ideas that are not presented in the passage or are minor ideas in the passage. **This question is worth 2 points.**

Write the letters of the answer choices in the spaces where they belong.
Refer to the full passage.

Different linear speeds at different latitudes on the Earth cause the prevailing winds in the Earth's Northern and Southern Hemispheres to deflect water movements, thus creating Ekman spirals.

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Answer Choices

(A) Due to the Coriolis force, icebergs move at a right angle to the prevailing wind.
(B) Because of the Earth's rotation, objects moving away from or toward the equator travel at different speeds in relation to fixed points at different latitudes.
(C) In order to reach the correct destination, an airplane pilot must adjust direction to compensate for the Coriolis force.
(D) Because of deflection and differences in linear speed, ocean currents move at an angle to the wind.
(E) Water at successively lower levels is deflected at an angle to the layer immediately above it, and this creates a spiral.
(F) Due to upwelling of water, marine life is rich in areas where Ekman spirals operate.