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### **QUESTION 1**

One of the most common methods that scientists use to determine the age of fossils is known as carbon dating. 14C is an unstable isotope of carbon that undergoes beta decay with a half-life of approximately 5,730 years. Beta decay occurs when a neutron in the nucleus decays to form a proton and an electron which is ejected from the nucleus. 14C is generated in the upper atmosphere when 14N, the most common isotope of nitrogen, is bombarded by neutrons. This mechanism yields a global production rate of 7.5 kg per year of 14C, which combines with oxygen in the atmosphere to produce carbon dioxide. Both the production and the decay of 14C occur simultaneously. This process continues for many half-lives of 14C, until the total amount of 14C approaches a constant. A fixed fraction of the carbon ingested by all living organisms will be 14C. Therefore, as long as an organism is alive, the ratio of 14C to 12C that it contains is constant. After the organism dies, no new 14C is ingested, and the amount of 14C contained in the organism will decrease by beta decay. The amount of 14C that must have been present in the organism when it died can be calculated from the amount of 12C present in a fossil. By comparing the amount of 14C in the fossil to the calculated amount of 14C that was present in the organism when it died, the age of the fossil can be determined.

After a 14C nucleus decays, the electron that is emitted enters lead and is stopped. What percentage of its kinetic energy does the electron transfer to lead?

A. 25%

B. 33%

C. 50%

D. 100%

Correct Answer: D

Kinetic energy, the energy of motion, is given by K.E. = (1/2)mv2, where m is the mass of the object and v is its speed. The electron emitted when a 14C nucleus decays is emitted with some initial speed and thus has kinetic energy. After it enters lead and is stopped, the electron\\'s speed is zero so its kinetic energy is also zero. In other words, all the electron\\'s kinetic energy is gone. Since energy is conserved, 100% of the electron\\'s kinetic energy must have been transferred somewhere, and in this case, it is transferred to the lead. Hence, choice D is correct.

#### **QUESTION 2**

There are two opposing theories of light: the particle theory and the wave theory. According to the particle theory, light is composed of a stream of tiny particles that are subject to the same physical laws as other types of elementary particles.

One consequence of this is that light particles should travel in a straight line unless an external force acts on them. According to the wave theory, light is a wave that shares the characteristics of other waves. Among other things, this means

that light waves should interfere with each other under certain conditions.

In support of the wave theory of light, Thomas Young\\'s double slit experiment proves that light does indeed exhibit interference. Figure 1 shows the essential features of the experiment. Parallel rays of monochromatic light pass through two

narrow slits and are projected onto a screen. Constructive interference occurs at certain points on the screen, producing bright areas of maximum light intensity. Between these maxima, destructive interference produces light intensity minima.



The positions of the maxima are given by the equation dsin = n, where d is the distance between the slits, is the angle shown in Figure 1, the integer n specifies the particular maxima, and is the wavelength of the incident light. (Note:

sin tan for small angles.)



### Figure 1

## θ

What is the angle for the third maximum (n = 3)?

# A. $3 \times 10^{-5}$ radians

# B. $3 \times 10^{-3}$ radians

## C. 0.3 radians

# D. 0.3 degrees

- A. Option A
- B. Option B
- C. Option C
- D. Option D
- Correct Answer: B

To solve this problem, apply the formula given in the passage which quantifies the positions of the intensity maxima. The formula is dsin = n, where d is the distance between the slits, is the angle, and is the wavelength. The note in the



passage says that sin when is small. You have to know that this approximation is only valid when is measured in radians. Making this approximation, we obtain d = n, and solving for we obtain n / d. Note that the distance units of and d can be anything as long as they

$$\theta = \frac{3(500 \times 10^{-9}m)}{5 \times 10^{-4}m} = 3 \times 10^{-3}$$
 radian

are the same. n is given in the question stem, and and d are given in Figure 1. Substituting, we obtain

which is choice B.

### **QUESTION 3**

Gauguin\\'s attitude toward art marked a break from the past and a beginning to modern art. Like all Post- Impressionist artists, he passed through an Impressionist phase but became quickly dissatisfied with the limitations of the style, and went on to discover a new style that had the directness and universality of a symbol and that concentrated on impressions, ideas and experiences. The beginning of his modern tradition lay in his rejection of Impressionism. He considered naturalism an error to be avoided. He was preoccupied with suggestion rather than description, seeking to portray not the exterior, but the essence of things in their purest, simplest, and most primitive form, which could only be achieved through simplification of the form. He firmly believed throughout his life that "art is an abstraction" and that "this abstraction [must be derived] from nature while dreaming before it." One must think of the creation that will result rather than the model, and not try to render the model exactly as one sees it. This was the birth of "Synthetism" or rather Synthetist-Symbolic, as Gauguin referred to it, using the term "symbolic" to indicate that the forms and patterns in his pictures were meant to suggest mental images or ideas and not simply to record visual experience.

Symbolism flourished around the period of 1885 to 1910 and can be defined as the rejection of direct, literal representation in favor of evocation and suggestion. Painters tried to give a visual expression to emotional experiences, and therefore the movement was a reaction against the naturalistic aims of Impressionism. Satisfying the need for a more spiritual or emotional approach in art, Symbolism is characterized by the desire to seek refuge in a dreamworld of beauty and the belief that color and line in themselves could express ideas. Stylistically, the tendency was towards flattened forms and broad areas of color, and features of the movement were an intense religious feeling and an interest in subjects of death, disease, and sin.

Similarly, "Synthetism" involved the simplification of forms into large-scale patterns and the expressive purification of colors. Form and color had to be simplified for the sake of expression. This style reacted against the "formlessness" of Impressionism and favored painting subjectively and expressing one\\'s ideas rather than relying on external objects as subject matters. It was characterized by areas of pure colors, very defined contours, an emphasis on pattern and decorative qualities, and a relative absence of shadows.

Gauguin\\'s new art form merged these two movements and succeeded in freeing color, form, and line, bringing it to express the artists\\' emotions, sensibilities, and personal experiences of the world around them. His style created a break with the old tradition of descriptive naturalism and favored the synthesis of observation and imagination. Gauguin sustained that forms are not discovered in nature but in one\\'s wild imagination, and it was in himself that he searched rather than in his surroundings. For this reason, he scorned the Impressionists for their lack of imagination and their mere scientific reasoning. Furthermore, Gauguin used color unnaturalistically for its decorative or emotional effect and reintroduced emphatic outlines. "Synthetism" signified for him that the forms of his pictures were constructed from symbolic patterns of color and linear rhythms and were not mere scientific reproductions of what is seen by the eye.

Dempsey, A., and Dempsey, A. (2010). Styles, Schools and Movements: The Essential Encyclopaedic Guide to Modern Art. London: Thames and Hudson.

According to passage information, what can we infer that Symbolism and Impressionism had in common?



- A. Both saw ideas as crucial to the impact of a work.
- B. Both focused on representing nature rather than man-made objects.
- C. Both considered the artist\\'s subjective experience to be a key element to the work.
- D. Both thought art needed to express the idiosyncratic nature of the artist rather than pleasing society.

### Correct Answer: C

This Reasoning Within the Text question asks you to reason about possible similarities between two art movements that are described as opposed. The passage states that in Impressionism, one paints the work "exactly as one sees it," and

in symbolism, "painters tried to give a visual expression to emotional experiences." Thus, in both forms of painting, the artist tries to portray a subjective internal experience, whether sensory or emotional.

A ?incorrect. The passage never mentions ideas as a component of Impressionist works. B ?incorrect. The passage gives no reason to believe that all Symbolist paintings were based on observing nature.

D ?incorrect. The passage never discusses the individual vs. society.

### **QUESTION 4**

Early experimentation on the single-celled organism Acetabularia led to important discoveries about the role of the nucleus in regulating cell function. Acetabularia is an enormous single cell with three distinct regions: a cap, a root-like rhizoid, and a stalk which connects the two. The following experiments were conducted to study the development of the cell:

### Experiment 1

The stalk of an Acetabularia was cut, fragmenting the cell. The fragment which included the cap died shortly afterwards while the fragment containing the rhizoid regenerated to form a complete Acetabularia.

#### Experiment 2

The nucleus from Acetabularia mediterranea, which has a flat cap, was transplanted into Acetabularia crenulata, which has a tufted cap, following removal of the Acetabularia crenulata nucleus. The Acetabularia crenulata cap eventually assumed the flat shape.

#### Experiment 3

The nucleus of Acetabularia mediterranea was removed from the young cell before it first formed a cap. A normal cap formed several weeks later. The cell proved to be inviable and died shortly thereafter.

#### Experiment 4

A young Acetabularia was fractioned into a number of portions before it first formed a cap. Several weeks later, both the portion containing the nucleus and the portion containing the apical tip of the stalk formed caps. The other portions did not form caps.

One explanation for the results of Experiment 4 is that the instructions for forming the cap are stored in the apical tip of the stalk several weeks prior to stalk formation. Which of the following pieces of evidence best supports this explanation?

A. Isolation of DNA coding for cap-inducing proteins from samples of Acetabularia taken several weeks prior to stalk



formation.

B. Exposure of a young Acetabularia to ribonuclease, which cleaves RNA, blocks cap formation.

C. Exchange of nuclei between Acetabularia crenulata and Acetabularia mediterranea leads to formation of the cap associated with each nucleus.

D. mRNA coding for cap-inducing proteins is found to accumulate in the stalk apex.

Correct Answer: D

The question stem asks for support of the fact that the information for forming the cap is stored in the apical tip of the stalk. This information is in the form of mRNA which is used as the template for translation of the proteins which coordinate

cap formation. The other choices may be true but they do not provide evidence for the storage of information in the apical tip.

Choice A is incorrect because the DNA coding for cap inducing proteins would be present at all times in the Acetabularia genome. This does not provide evidence for the storage of information in the stalk tip. Choice B is incorrect because,

although exposure of the Acetabularia to ribonuclease and the consequent cleavage of RNA would temporarily block formation of the cap (until more RNA is transcribed), this does not provide evidence for the storage of information in the

apical stalk segment. Rather, it provides evidence that RNA is the conveyor of information.

Choice C is incorrect because although the passage describes this exchange of nuclei in Experiment 2, this does not provide evidence for the storage of information in the apical stalk.

### **QUESTION 5**

According to Boyle\\'s Law, if a gas expands in volume from 5 L to 10 L and has an initial pressure of 1 atm, what is the final pressure?

A. 5 atm

B. 2 atm

C. 0.5 atm

D. 1 atm

Correct Answer: C

Boyle\\'s Law states that P1V1 = P2V2.

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