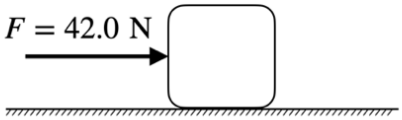
Physics MCQ Exam Solution

1. A box with a weight of 100 N is at rest on a horizontal surface. The coefficient of kinetic friction and the coefficient of static friction between the box and the surface are $\mu_k = 0.400$ and $\mu_S = 0.500$, respectively. If the force $F = 42.0$ N is applied on the box as shown in the figure, what is the magnitude and direction of the friction acting on the box?

   A. 40.0 N to the left
   B. 42.0 N to the left
   C. 50.0 N to the left
   D. 50.0 N to the right



Solution

Correct Choice: B

Maximum static friction: $f_{s,\max} = \mu_s N = 0.500 \times 100 \text{ N} = 50.0 \text{ N} > F$

Therefore, the box doesn't move. $\Sigma F_x = 0$

The static friction in this case is $f_s = 42.0$ N to the left.

2. Which object has the greatest magnitude of the acceleration? Assume that all objects move with constant acceleration in straight line.

A. A vehicle accelerates from rest to 100 km/h within 4.00 s.
B. A rock during a free fall near the surface of the Earth.
C. A vehicle with an initial speed of 60.0 km/h comes to rest in 3.20 s.
D. A vehicle starting from rest takes 6.50 s to cover a distance of 250 m.

Solution

Correct Choice: D

A. $a = \frac{\Delta v}{\Delta t} = \frac{(100-0)\times 1000}{4.00\times 60\times 60}\frac{\text{m}}{\text{s}^2} = 6.94\ \text{m/s}^2$

B. $a = g = 9.80\ \text{m/s}^2$

C. $a = \frac{\Delta v}{\Delta t} = \frac{(0-60)\times 1000}{3.200\times 60\times 60}\frac{\text{m}}{\text{s}^2} = -5.21\ \text{m/s}^2$ -> $|a| = 5.21\ \text{m/s}^2$

D. $\Delta x = ut + \frac{1}{2}at^2$ -> $a = \frac{2\Delta x}{t^2} = \frac{2\times 250}{6.5^2}\frac{\text{m}}{\text{s}^2} = 11.8\ \text{m/s}^2$ **the greatest value**

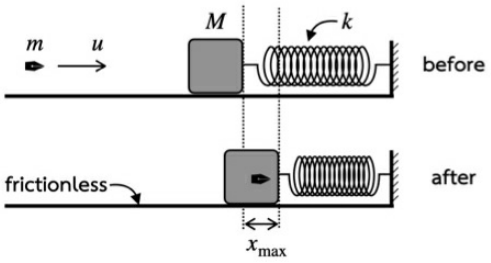
3. A bullet of mass m is shot into a stationary block of mass M. The block rests on a frictionless floor and is attached to a massless spring with a spring constant k. The bullet embeds itself in the block upon impact. Subsequently, the combined mass compresses the spring to a maximum displacement of $x_{\max}$, as illustrated in the figure. Determine the initial velocity u of the bullet in terms of $m, M, k,$ and $x_{\max}$.

A. $\frac{x_{\max}}{m}\sqrt{k(m+M)}$

B. $\frac{(m+M)}{m}x_{\max}\sqrt{k}$

C. $x_{\max}\sqrt{\frac{k}{m}}$

D. $x_{\max}\sqrt{\frac{k}{m+M}}$



Solution

Correct Choice: A

1. collision between the bullet and the block
conservation of momentum:

$$mu = (m+M)v$$
$$v = \frac{mu}{m+M} \quad (1)$$

2. The combined mass compresses the spring
conservation of mechanical energy:

kinetic energy of the combined mass = elastic potential energy

$$\frac{1}{2}(m+M)v^2 = \frac{1}{2}kx_{\max}^2 \quad (2)$$
$$v = x_{\max}\sqrt{\frac{k}{m+M}} \quad (3)$$

Plug v from (1) into (3):

$$u = \frac{m+M}{m} \times x_{\max}\sqrt{\frac{k}{m+M}} \quad (4)$$
$$u = (x_{\max}/m)\sqrt{k(m+M)} \quad (5)$$

This is the expression in choice A.

4. When placed in a liquid of density ρ_A, a sphere sinks and displaces a volume V_A of liquid, as shown in the figure.

When placed in a liquid of density ρ_B, the same sphere floats with half of its volume appears over the surface of the liquid.

When placed in a liquid of density ρ_C, the same sphere floats.

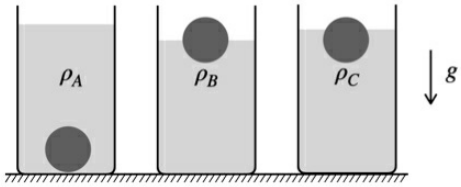
Determine the magnitude of the buoyant force exerted by the liquid of density ρ_C on the sphere.

A. $\rho_C V_A\, g$

B. $\frac{1}{2}\rho_A V_A\, g$

C. $\frac{1}{2}\rho_B V_A\, g$

D. Insufficient information



Solution

Correct Choice: C

When placed in a liquid of density ρ_A, a sphere sinks and displaces a volume V_A of liquid.

Obtained information: sphere's volume $V = V_A$

When placed in a liquid of density ρ_B, the same sphere floats with half of its volume appears over the surface of the liquid.

Obtained information: the sphere floats, buoyant force = weight of the sphere

$$\rho_B \frac{V_A}{2} g = m_s g = \rho_s V_A g$$

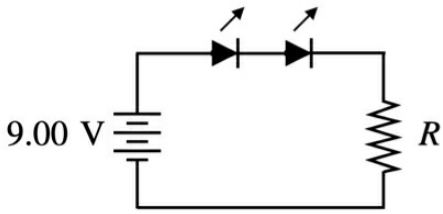
density of the sphere: $\rho_s = \rho_B/2$

mass of the sphere: $m_s = \rho_B V_A/2$

When placed in a liquid of density ρ_C, the same sphere floats.

Obtained information: the sphere floats, buoyant force = weight of the sphere = $\frac{1}{2}\rho_B V_A g$ **

5. Two identical LEDs are connected as shown in the circuit diagram. Each LED needs a current of 10.0 mA and a potential difference of 1.20 V to operate correctly. Calculate the resistance of a resistor *R* for this circuit to operate under the conditions given above.



A. 330 Ω

B. 390 Ω

C. 660 Ω

D. 780 Ω

Solution

Correct Choice: C

Two LEDs are connected in series, the current through each of them are the same I = 10.0 mA.

I = 10.0 mA is also the current throughout the circuit.

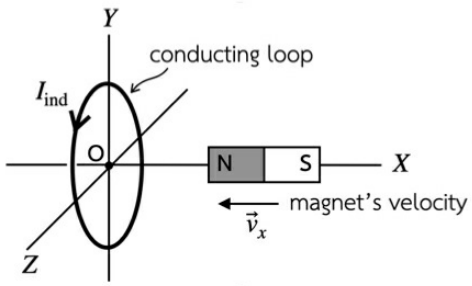
Potential difference across two LEDs is: 1.20 + 1.20 = 2.40 V.

Potential across the resistor is then: 9.00 - 2.40 = 6.60 V.

Therefore, R = $\Delta V/I$ = 6.60/0.0100 = 660 Ohms. ***

6. Identify the diagram that shows the **incorrect** direction of the induced current I_{ind} in the conducting loop. In all the figures, the conducting loops are in y-z plane and the currents are in the counter-clockwise direction when viewed from the positive x-axis.

A.



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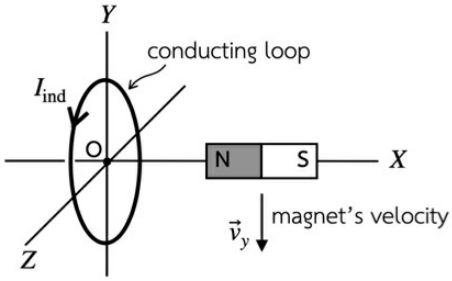
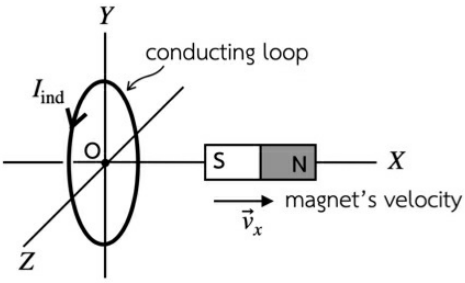
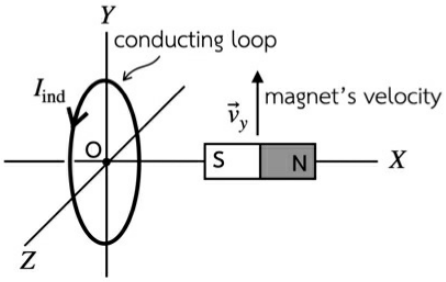


C.



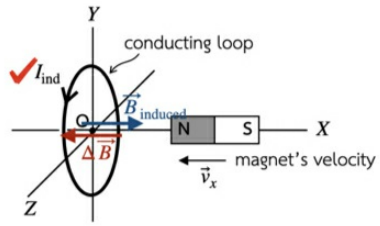
D.



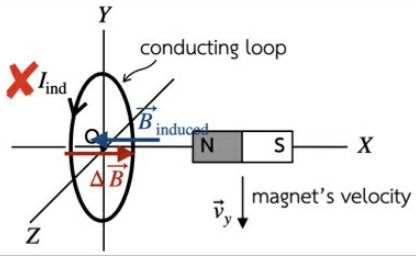
Solution

Correct Choice: B

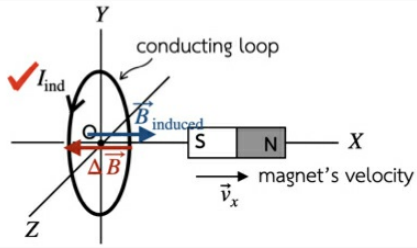
A.



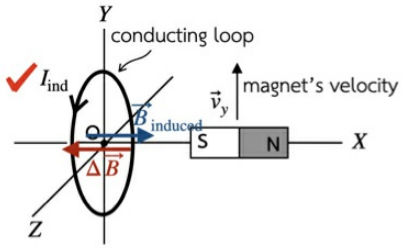
B.



C.

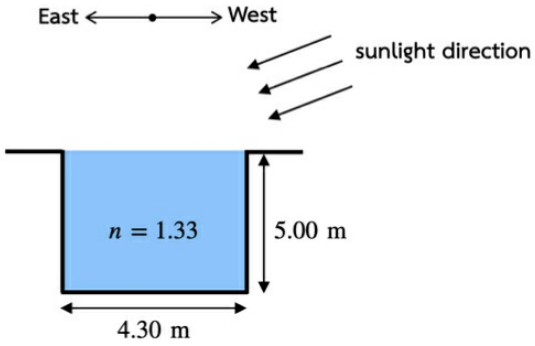


D.



7. The rectangular pool measuring 4.30 meters in width and 5.00 meters in depth is filled with water to the top. As shown in the figure, the 4.30-meter side aligns with the East-West direction. The pool is situated near the equator, where the Sun is directly overhead at noon. At approximately what time will the bottom of the pool begin to be entirely shaded? Given that the index of refraction of water is 1.33.

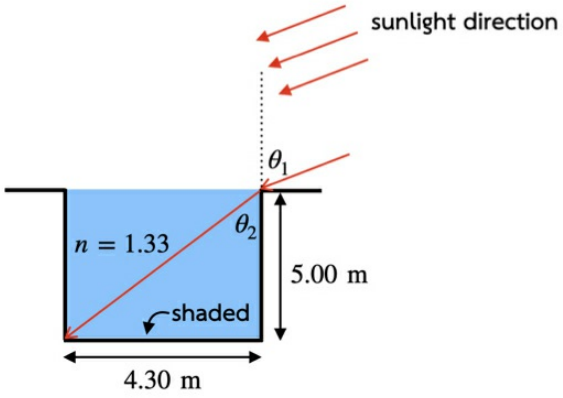
A. 3:00pm
B. 3:30pm
C. 4:00pm
D. 4:30pm



Solution

Correct Choice: C

The bottom of the pool is completely shaded when the sunlight ray from the edge of the pool refract to the opposite corner. None of the light is incident on the bottom of the pool.



$$\theta_2 = \tan^{-1}\left(\frac{4.3}{5.0}\right) = 40.70^\circ$$

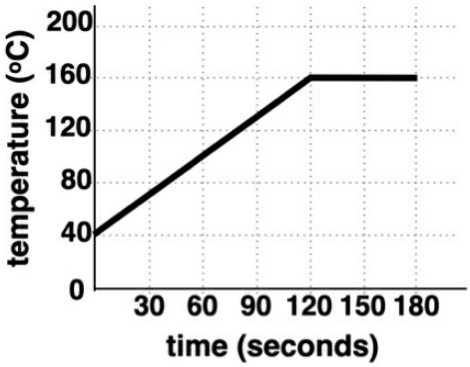
From Snell's law:

$$n_{\text{air}} \sin\theta_1 = n_{\text{water}} \sin\theta_2$$

$$\theta_1 = \sin^{-1}\left[1.33\sin(40.70^\circ)\right] = 60.1^\circ \approx 60^\circ$$

The Sun moves 15° every an hour. 60° from directly overhead position takes 4 hours. Therefore, it's 4pm.

8. An insulated container holds 200 grams of solid thermoplastic. Heat is supplied to the thermoplastic at a constant rate of 400 J/s for 180 s. The temperature of the thermoplastic is measured and recorded, and the results are presented in the graph below.
Consider the following statements:



I. The specific heat of this thermoplastic is 2.00 kJ/kg K.
II. The melting point of this thermoplastic is 160°C.
III. After 120 seconds, only liquid form of the thermoplastic is in the container.
IV. The specific latent heat of fusion of this thermoplastic is 12.0 kJ/kg.

Which of these statements is true?
A. I and II only
B. II and III only
C. I, II and IV only
D. I, II and III onlySolution

Correct Choice: A

I. The specific heat can be obtained from 0 - 120 s in the graph. $\Delta T = 120^{\circ}\text{C}$

from $Q = mc\Delta T \rightarrow c = \dfrac{Q}{m\Delta T}$

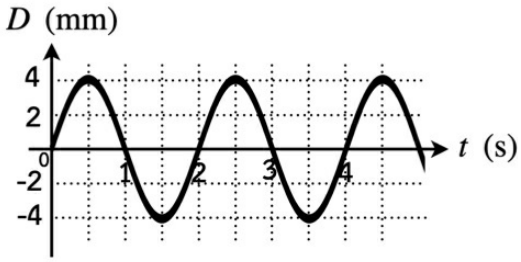
$$c = \frac{400\ \text{J/s} \times 120\ \text{s}}{0.200\ \text{kg} \times 120^{\circ}\text{C}} = 2.00\ \text{kJ/kg} \cdot \text{K}$$

II. The melting point is **160°C**

III. After 120 seconds, the thermoplastic starts melting. There will be a mixture of liquid and solid thermoplastic in the container. X

IV. The latent heat is much greater than 12 kJ/kg. X

9. The graph below shows the displacement (*D*) of a medium at x = 0.0 cm as a function of time (*t*) for a wave traveling in the +x direction at a speed of 5.0 cm/s. Determine the wavelength of this wave.



A. 2.0 cm
B. 5.0 cm
C. 8.0 cm
D. 10 cm

Solution

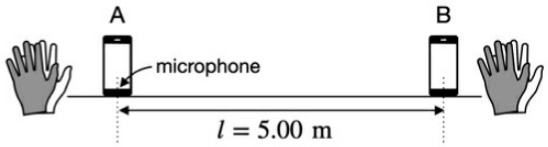
Correct Choice: D

According to the graph, wave's period is T = 2.0 s. Then the frequency is f = 1/2.0 = 0.50 Hz.

From $v = f\lambda, \rightarrow \lambda = v/f = 5.0/0.5 = 10$ cm

10. A smartphone can be used as an acoustic stopwatch. It measures the time interval between two consecutive sound events captured by its microphone. The timing starts when the first sound pulse reaches the microphone and stops when the second sound pulse is detected.

In an experiment aimed at measuring the speed of sound in the air $v = 340\ \mathrm{m/s}$, two smartphones in acoustic stopwatch mode are placed with their microphones located at a distance $l = 5.00\ \mathrm{m}$ meters apart, as shown in Figure 1. During the measurement, one student claps next to the microphone of phone A, and a few seconds later, another student claps next to the microphone of phone B. Each clap triggers both phones but at different moments due to the time it takes for the sound waves to travel. What is the possible correct reading from phone A and phone B?



A. Phone A: 0.0147 s, Phone B: 0.0147 s
B. Phone A: 2.0147 s, Phone B: 2.0000 s
C. Phone A: 3.1000 s, Phone B: 3.1294 s
D. Phone A: 2.1294 s, Phone B: 2.1000 s

Solution

Correct Choice: D

When one student claps next to the phone A, the phone A starts timing and l/v seconds later the phone B start timing. l/v is the propagation time of the sound wave from phone A to phone B.

Then the other student claps next to phone B, phone B stops timing and l/v seconds later the phone A stops timing.

Therefore, time duration shown in phone A is longer than in phone B, because the phone A starts timing first but stops later. The time duration in phone A is longer than in phone B by $2l/v$ = 0.0294s.

11. Use data from the table to answer the question.

Indicator	K_A of indicator at 25°C	Color change (Acid to basic form)
Bromophenol blue	1.4×10^{-4}	Yellow → Blue
Bromocresol green	2.1×10^{-5}	Yellow → Blue

Colors of both bromophenol blue and bromocresol green turn yellow when the ratio of acid form: basic form is greater than 25:1, while they turn blue when the ratio of basic form: acid form is greater than 5:1. Both indicators are green in between the pH that corresponds to 25:1 and 5:1 ratios. What color could a solution of bromophenol blue appear if it is at the same pH as a solution of bromocresol green that appears green?

A. Blue
B. Green
C. Yellow or Green
D. Green or Blue

Solution:

$$HIn + H_2O \rightleftharpoons In^- + H_3O^+$$

(yellow) (Blue)

$$Ka = \frac{[In^-][H3O^+]}{[HIn]} \quad \ldots\ldots\ldots \textbf{(Eq.1)}$$

Yellow ⇒[HIn]/[In$^-$] > 25/1

Blue ⇒[In$^-$]/[HIn] > 5/1

pH of Bromecresol green to turn yellow using Eq.1

$$2.1 \times 10^{-5} = 1 \times [H_3O^+]/25$$

$$[H_3O^+] = (2.1 \times 10^{-5})(25) = (5.25 \times 10^{-4})$$

$$pH = -\log[H_3O^+] = -\log(5.25 \times 10^{-4})$$

$$pH = 4\text{-}0.72 = 3.28$$

pH of Bromecresol green to turn blue using Eq.1

$$2.1 \times 10^{-5} = 5 \times [H_3O^+]/1$$

$$[H_3O^+] = (2.1 \times 10^{-5})/5 = (4.2 \times 10^{-6})$$

$$pH = -\log[H_3O^+] = -\log(4.2 \times 10^{-6})$$

$$pH = 6\text{-}0.62 = 5.38$$

Therefore, pH range of Bromecresol green is

yellow ←3.28 - 5.38→ blue

range of green

pH of Bromophenol blue to turn yellow using Eq.1

$$1.4 \times 10^{-4} = 1 \times [H_3O^+]/25$$

$$[H_3O^+] = (1.4 \times 10^{-4})(25) = 3.5 \times 10^{-3}$$

$$pH = -\log[H_3O^+] = -\log(3.5 \times 10^{-3})$$

$$pH = 2.46$$

pH of Bromophenol blue to turn blue using Eq.1

$$1.4 \times 10^{-4} = 5 \times [H_3O^+]/1$$

$$[H_3O^+] = (1.4 \times 10^{-4})/5 = 2.8 \times 10^{-5}$$

$$pH = -\log[H_3O^+] = -\log(2.8 \times 10^{-5})$$

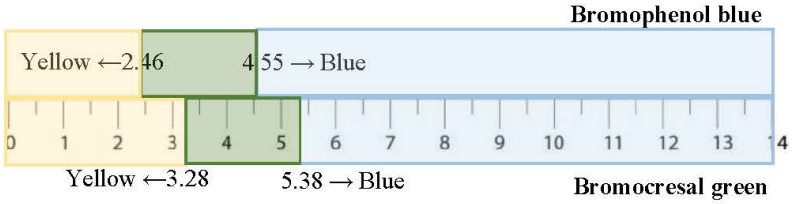
$$pH = 4.55$$

Therefore, pH range of Bromophenol blue is

yellow ←2.46 - 4.55→ blue

range of green

Compare the range of Bromocresol green & Bromophenol blue ⇒ pH of solution developing green color for Bromocresol green can cause Bromophenol blue to develop either Green or Blue



12. From the following observation under standard condition:

(i) Metal M dissolves in H_2SO_4 (aq), but not in HCl (aq)

(ii) Metal M displaces Ag^+ (aq), but not Sn^{4+} (aq)

when $2H^+ + 2e^- \rightarrow H_2$ ($E°_{red}$ = 0.00 V)

$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$ ($E°_{red}$ = 0.13 V)

$SO_4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + H_2O$ ($E°_{red}$ = 0.20 V)

$Ag^+ + e^- \rightarrow Ag$ ($E°_{red}$ = 0.80 V)

Estimate the $E°_{red}$ from the half reaction M^+ (aq) + e^- → M(s)

A. 0.00 V < E°

B. 0.00 V < E° < 0.13 V

C. $0.13\ V < E^\circ < 0.20\ V$

D. $0.20\ V < E^\circ < 0.80\ V$

Solution:

(i) M dissolves in H_2SO_4 but not in HCl which indicates that M doesn't give e^- and H^+

Which mean that Reduction potential (E°_{red}) of $M^{n+} + ne^- \rightarrow M$ is higher than

$2H^+ + 2e^- \rightarrow H_2$ ($E^\circ_{red} = 0.00\ V$)

Dissolution of M in H_2SO_4 indicates that M can give e^- to SO_4^{2-}

From Reduction potential information

$SO_4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + H_2O$ ($E^\circ_{red} = 0.20\ V$)

So, E° of $M^{n+} + ne^- \rightarrow M$ is less than 0.20 V

Therefore, (i) $0 < E^\circ_{Mn+/M} < 0.20$

(ii) M causes Ag^+ to disappear, but not Sn^{4+}

Which mean that E° of M is lower than $Ag^+ + e^- \rightarrow Ag$ ($E^\circ = 0.80\ V$)

But higher than $Sn^{4+} + 2e^- \rightarrow Sn^{2+}$ ($E^\circ = 0.13\ V$)

Therefore, (ii) $0.13 < E^\circ Mn+/M < 0.80$

From both (i) & (ii)

$0.13 < E^\circ Mn+/M < 0.20$

13. A sample of 0.5 g silver metal is obtained from two different silver sources. Source 1 has two stable isotopes, ^{107}Ag (106.91 g/mol) and ^{109}Ag (108.90 g/mol), with isotope abundance of 51.84% and 48.16%, respectively. Source 2 contains ^{107}Ag (106.91 g/mol) and ^{109}Ag (108.90 g/mol), with isotope abundance of 44.80% and 55.20%, respectively. If the isotope ratio (^{107}Ag: ^{109}Ag) in the the silver sample is 1:1, determine the percentage by mass of silver from source 2 in the sample.

A. 12%

B. 26%

C. 32%

D. 51%

Solution:

Average atomic weight of Ag from Source1 = $(106.91\ g/mol)(0.5184) + (108.90\ g/mol)(0.4816)$

$= 55.422 + 52.444 = 107.868\ g/mol$

Average atomic weight of Ag from Source2 = $(106.91\ g/mol)(0.4480) + (108.90\ g/mol)(0.5520)$

$= 47.896 + 60.113 = 108.009\ g/mol$

In the mixture $\Rightarrow$ (mol of ^{107}Ag)/(mol of ^{109}Ag) = 1

$$= \frac{mol\ of\ 107Ag(No.1) + mol\ 107Ag(No.2)}{mol\ of\ 109Ag(No.1) + mol\ 109Ag(No.2)}$$

mol of ^{107}Ag(No.1) + mol of ^{107}Ag(No.2) = mol of ^{109}Ag(No.1) +mol of ^{109}Ag(No.2)

if mass of Ag from source No.2 = x gram, then

$$\left(\frac{(0.5-x)}{107.868}\frac{51.84}{100}\right)mol + \left(\frac{(x)}{108.009}\frac{44.80}{100}\right)mol = \left(\frac{(0.5-x)}{107.868}\frac{48.16}{100}\right)mol + \left(\frac{(x)}{108.009}\frac{55.20}{100}\right)mol$$

So, $(2.403 \times 10^{-3})mol - (4.806 \times 10^{-3})\ mol/g\ (x)\ g + (4.148 \times 10^{-3})\ mol/g\ (x)\ g =$

$(2.232 \times 10^{-3})\ mol - (4.465 \times 10^{-3})\ mol/g\ (x)\ g + (5.111 \times 10^{-3})\ mol/g\ (x)\ g$

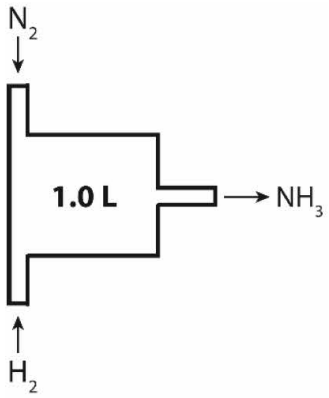
$(2.403 - 2.232)10^{-3}$ *mol* = (5.111 = 4.465 + 4.866 - 4.148)10^{-3} *mol/g* (x) *g*

(0.171×10^{-3}) *mol* = (1.304×10^{-3}) *mol/g* (x) *g*

x = (0.171×10^{-3}) *mol*/(1.304×10^{-3}) *mol/g* = 0.131 *g*

Therefore, Ag from source No.2 = (0.131 × 100)/ 0.5 = 26.22% ≈ 26%

14. Assume that the reactor under the condition given below starts at vacuum, and then N_2 and H_2 are fed at constant rates of 2.0 g/min and 0.43 g/min for N_2 and H_2, respectively. Once 8.4 g of N_2 is accumulated in the reactor, ammonia is selectively removed from the reactor at a constant rate to maintain a chemical equilibrium within the reactor. If the equilibrium constant K_c of this reaction is 3.0 at this temperature, how many grams of ammonia present in the reactor at any given time?



A. 4.8 g

B. 8.4 g

C. 10 g

D. 14 g

At equilibrium, $[N_2]$ = (8.4 g)/(28.02 g/mol) = 0.30 mol in a 1-L reactor.

Since the reactor starts from vacuum, to which N_2 and H_2 are introduced at the rates of stoichiometric proportion, $[H_2] = 3[N_2]$ at equilibrium.

We then have

$3.0 = [NH_3]^2/([N_2][H_2]^3) = [NH_3]^2/([N_2](3[N_2])^3) = [NH_3]^2/(27[N_2]^4)$

Therefore,

$[NH_3] = 9[N_2]^2 = 9(0.30)^2 = 0.81$ mol/L = 14 g/L or 14 g in this reactor.

15. A student prepares a 1.0 M solution of $PtCl_4 \cdot 5NH_3$. The student first tests the conductivity of the solution and it conducts electricity equivalent to the solution of 4.0 M of ions. The student titrates 10.00 cm^3 of 1.0 M solution of $PtCl_4 \cdot 5NH_3$ with a 1.5 M silver solution and 20.00 cm^3 of 1.5 M Ag^+ is required to reach the end point. A titration was performed to determine the amount of Cl^- in the solution according to this reaction.

$$Ag^+ (aq) + Cl^- (aq) \rightarrow AgCl\ (s)$$

What are the possible species in the prepared $PtCl_4 \cdot 5NH_3$ solution?

A. $[Pt(NH_3)_5\ Cl]^{3+}(aq) + 3Cl^-\ (aq)$

B. $[Pt(NH_3)_2Cl_4]\ (aq) + 3NH_3(aq)$

C. $[Pt(NH_3)_5]^{4+}(aq) + 4Cl^-\ (aq)$

D. $[Pt(NH_3)_4\ Cl_2]^{2+}(aq) + 2Cl^-\ (aq) + NH_3(aq)$

Solution: A) (molecular structure, stoichiometry, coordination compound)

$$[Pt(NH_3)_5Cl]Cl_3 \rightarrow [Pt(NH_3)_5Cl]^{3+}\ (aq) + 3Cl^-\ (aq)$$

1 mol of the complex needs 3 mol of Ag+

So, there are 3 mol of free Cl^- ions for 1 mol of the complex

16. An element X is in the third period of the periodic table. The data for successive ionization energy of the element X are IE_1 = 1012 kJ/mol, IE_2 = 1907 kJ/mol, IE_3 = 2914 kJ/mol, IE_4 = 4964 kJ/mol, IE_5 = 6274 kJ/mol, IE_6 = 21268 kJ/mol, and IE_7 = 25431 kJ/mol. Which of the following statements is correct?

A. A chloride compound of the element could have molecular formula of XCl_6.
B. One chemical formula for the oxide of the element X is X_4O_{10}.
C. An aqueous solution any oxide of the element X would turn red litmus paper blue.
D. Only one unpaired electron can be found in the electron configuration of the ground state atom.

Solution:
X = P; IE_1-IE_5 the outermost valence electrons have lower IE than the inner-shell.
A. incorrect; PCl_3 trigonal planar or PCl_5 trigonal bipyramidal
B. correct; P_4O_6, P_4O_{10}
C. incorrect; $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ turns blue litmus paper red
D. incorrect; both electrons have n = 3, l = 1, m_l = -1 with m_s = ½ and -½, which means they are in the same orbital but spins oppositely. Electrons of P cannot be in the same orbital in the ground state (violates Hund's rule).

17. If only α ($^{4}_{2}$He nucleus) and β^{-} (e-) particles (electrons) are emitted during the following chains of natural radioactive decay:

i. $^{232}_{90}Th \rightarrow {}^{208}_{82}Pb$

ii. $^{235}_{92}U \rightarrow {}^{207}_{82}Pb$

iii. $^{237}_{93}Np \rightarrow {}^{209}_{83}Bi$

iv. $^{238}_{92}U \rightarrow {}^{206}_{82}Pb$

Which decay processes emit the fewest α and the most β^{-} particles, respectively? (beta decay: $n \rightarrow p^{+} + e^{-}$)

A. i) and ii)

B. iii) and iv)

C. i) and iv)

D. ii) and iii)

Solution:

i) $^{232}_{90}Th \rightarrow {}^{208}_{82}Pb + {}^{4}_{2}He + {}^{0}_{-1}\beta$

$232 = 208 + 4\alpha$; $\alpha = (232-208)/4 = 6$

$90 = 82 + 2\alpha - \beta$

$= 82 + 2\times6 - \beta$

$\beta = 4$

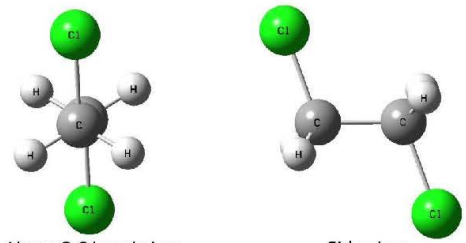
ii) $\alpha = 7, \beta = 4$

iii) $\alpha = 7, \beta = 4$

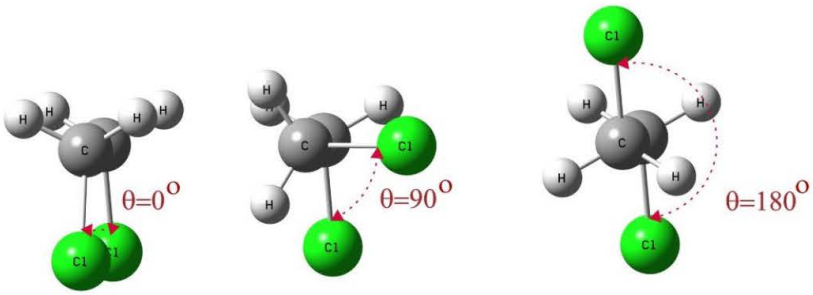
iii) $\alpha = 8, \beta = 6$

18. 1,2-dichloroethane or ethylene dichloride (EDC) is a precursor to vinyl chloride which is used to produce polyvinyl chloride (PVC). Its structure is shown below

used to produce polyvinyl chloride, ... shown below.



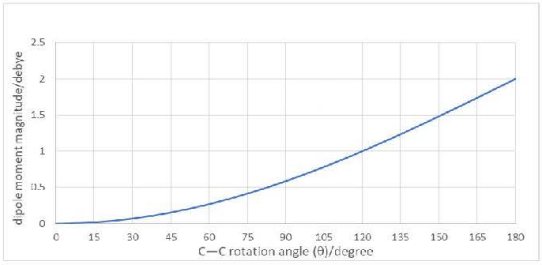
The C—C bond rotation in EDC can occur almost freely. This can be thought of as having one CH_2Cl group stationary and having another CH_2Cl rotating around the C—C axis. Figure below shows the change of molecular structure as the function of C—C rotation angle (θ) viewed along the C—C bond.



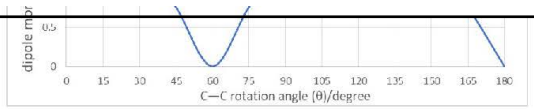
The dipole moment is the quantitative measurement of how polar the molecule is. The dipole moment of the molecule can be calculated from the vector addition of bond polarity.

Which is the correct plot of dipole moment magnitude as the function of C—C rotation angle (θ)

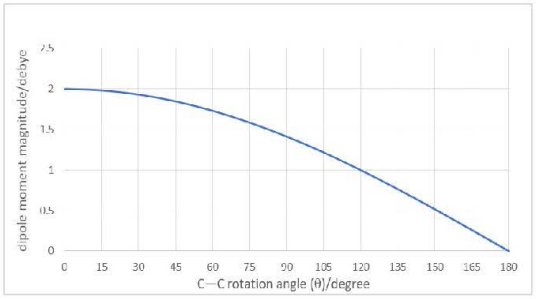
A.



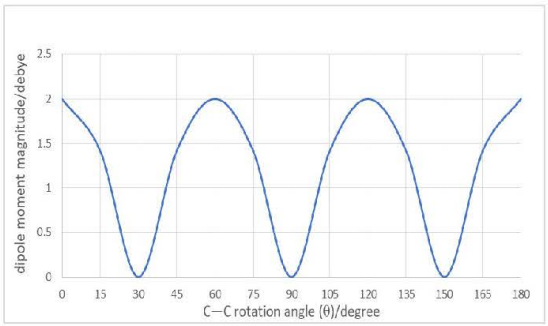
B.


dipole mor
0.5
0
0 15 30 45 60 75 90 105 120 135 150 165 180
C—C rotation angle (θ)/degree

C.


dipole moment magnitude/debye
2
1.5
1
0.5
0
0 15 30 45 60 75 90 105 120 135 150 165 180
C—C rotation angle (θ)/degree

D.


dipole moment magnitude/debye
2.5
2
1.5
1
0.5
0
0 15 30 45 60 75 90 105 120 135 150 165 180
C—C rotation angle (θ)/degree

19. A gas mixture with the total mass of 168 g consists of propane (C_3H_8), propene (C_3H_6), and propyne (C_3H_4). It is found that the mass percentage of propene in this gas mixture is 50%. Upon burning this mixed gas in the excess amount of oxygen, the mass of CO_2 produced from the complete combustion of propane is equal to that produced from the complete combustion of propyne. What is the mole fraction of propyne in this gas mixture?

A. 0.10

B. 0.25

C. 0.50

D. 0.75

Solution:

We already know that there are 84 g of propene.

Let the amount of propane = 84 – x g

And the amount of propyne = x g

Let y = the amount in grams of CO_2 produced from propane/propyne

For the combustion of propane: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

$$\text{Mol of } C_3H_8 = \frac{1}{3} \times \text{mole of } CO_2$$

$$\frac{84-x}{44.11} = \frac{1}{3} \times \frac{y}{44.01} \qquad \ldots\ldots\ldots (1)$$

For the combustion of propyne: $C_3H_4 + 4O_2 \rightarrow 3CO_2 + 2H_2O$

$$\text{Mol of } C_3H_4 = \frac{1}{3} \times \text{mole of } CO_2$$

$$\frac{x}{40.07} = \frac{1}{3} \times \frac{y}{44.01} \qquad \ldots\ldots\ldots (2)$$

From (1) and (2), we obtain

$$\frac{84-x}{44.11} = \frac{x}{40.07}$$

$$\therefore x = 40$$

Therefore, the mole fraction of propyne $= \dfrac{\frac{40}{40}}{\frac{40}{40}+\frac{84}{42}+\frac{44}{44}} = 0.25$

20. A series of sulfate samples is to be analyzed by precipitation as $BaSO_4$. If it is

known that the sulfate content in these samples ranges between 20% and 55%, what minimum sample mass should be taken to ensure that a precipitate mass no smaller than 0.200 g is produced?

A. 0.150 g

B. 0.200 g

C. 0.220 g

D. 0.412 g

Solution:

Let S_w = mass of sample in grams

$$M_{BaSO_4} = 233.4\ g/mole \qquad M_{SO_4{}^{2-}} = 96.07\ g/mole$$

$$0.200\ g\ BaSO_4 \times \frac{1\ mole\ BaSO_4}{233.4\ g} \times \frac{1\ mole\ SO_4{}^{2-}}{1\ mole\ BaSO_4} = 8.57 \times 10^{-4} mole\ SO_4{}^{2-}$$

$$\frac{8.57 \times 10^{-4} mole\ SO_4{}^{2-} \times \frac{96.07\ g\ SO_4{}^{2-}}{mole}}{S_w\ g\ sample} \times 100\% = 20\%\ SO_4{}^{2-}$$

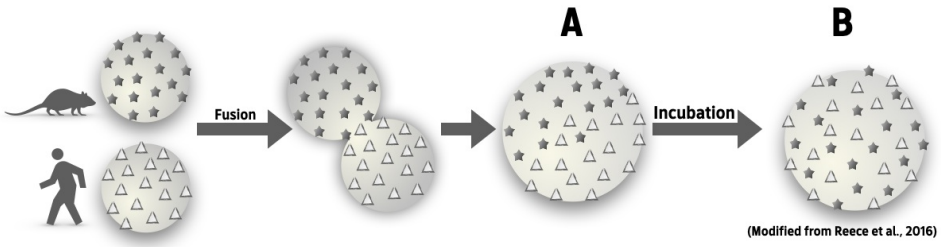
$$S_w\ g\ sample = \frac{8.57 \times 10^{-4} mole\ SO_4{}^{2-} \times \frac{96.07\ g\ SO_4{}^{2-}}{mole} \times 100\%}{20\%} = 0.412\ g\ sample$$

Biology questions

Marking scheme

point	1	0	-0.25
Criteria	Correct answer	No answer	Incorrect answer

21. Scientists labeled membrane proteins (proteins that exist in the plasma membrane) of a mouse cell and a human cell with two different markers. Two cells were fused forming a hybrid cell. Initially, proteins on the hybrid cell's surface were observed as state A. Normally, after incubating the cell at 37 °C for 1 hour, proteins from different sources would disperse throughout the surface of the cell as in state B.



However, if the cell took 2 hours to transform from state A to state B, which of the following could be the reason(s)?

I. Cell membrane possessed a greater unsaturated-to-saturated phospholipids ratio.
II. Incubation was carried out at 18 °C.

A. I only
B. II only
C. I and II
D. neither I nor II

Answer B. II only

Explanation

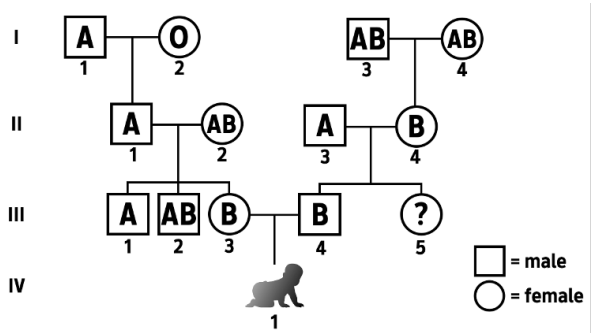
A. I only	✖	This is **incorrect**. A relatively greater unsaturated-to-saturated phospholipids ratio will increase membrane fluidity, hence shorter incubation time required for full protein dispersion.
B. II only	✔	This is **correct**. At the temperature much lower than 37 °C, labelled proteins migrate more slowly due to increased viscosity/less fluidity of the membrane, thus, requiring more time to be fully dispersed throughout the entire surface of the cell.
C. I and II	✖	This is **incorrect**.
D. neither I nor II	✖	This is **incorrect**.

References

Frye, L. D., & Edidin, M. (1970). The rapid intermixing of cell surface antigens after formation of mouse-human heterokaryons. J Cell Sci. 7(2): 319-35. doi: 10.1242/jcs.7.2.319.

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 128-129.

22. The pedigree below illustrates the ABO blood type inheritance of two lineages.



Which statements are true according to the pedigree?

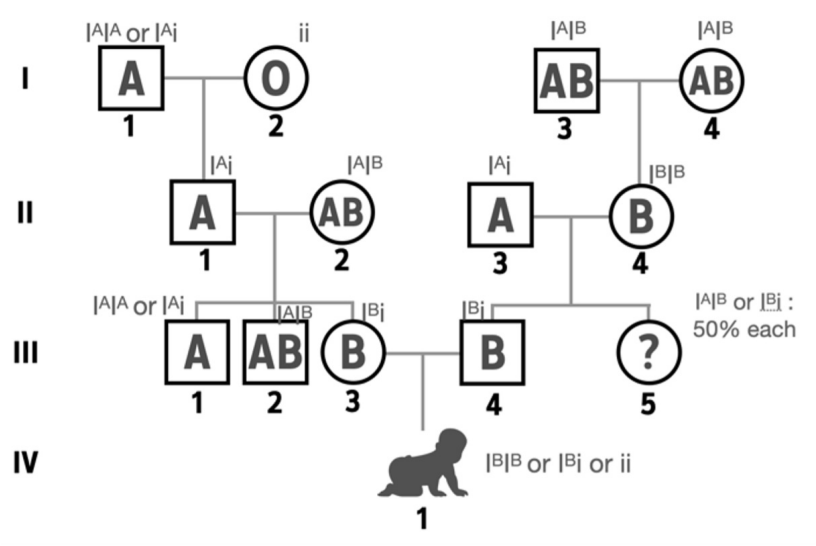
I. The baby IV-1 cannot be heterozygote.
II. The probability of III-5 to be a B-type is 0.5.

III. The genotype of II-1 can either be homozygous or heterozygous.
IV. If III-1 is married to an AB-type woman, there is a chance for a child to be B-type.

A. I and II
B. II and III
C. III and IV
D. II and IV

Answer D. II and IV

Explanation

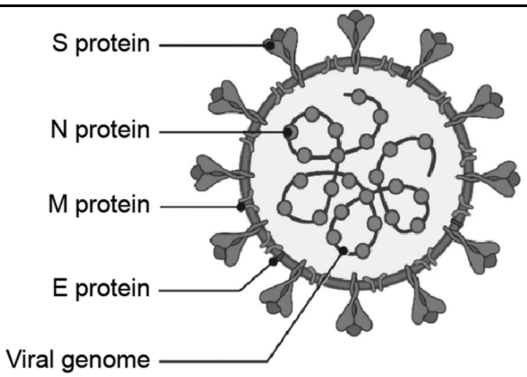


A. I and II	✖	This is **incorrect**. Statement I is incorrect because the baby can be either homozygote or heterozygote i.e., $1I^BI^B : 2I^Bi : 1ii$.
B. II and III	✖	This is **incorrect**. Statement III is incorrect because the genotype of II-1, who is A-type, can only be heterozygous (I^Ai) as his mother (I-2) is O-type whose genotype is strictly ii.
C. III and IV	✖	This is **incorrect**. Statement III is incorrect because the genotype of II-1, who is A-type, can only be heterozygous (I^Ai) as his mother (I-2) is O-type whose genotype is strictly ii.
D. II and IV	✔	This is **correct**. In statement II, the probability of III-5 to be a B-type is 0.5 because her mother (II-4), who is a daughter of AB-type parents, is homozygous B-type (I^BI^B) and her father (II-3) has to be heterozygous (I^Ai) as III-4 (III-5´s brother) is B-type. Thus, the genotype of III-5 can either be I^AI^B or I^Bi with an equal probability. In statement IV, the genotype of III-1 can either be I^AI^A or I^Ai as his father (II-1) is I^Ai. If he is assumably I^Ai, his child can probably be B-type when he has a child with an AB-type woman.

Reference

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 280-284.

23. The following figure shows the structure of a coronavirus. The virus is an RNA virus that has a lipid-rich envelope derived from the membrane of the host cell.



(Modified from https://www.biophysics.org/blog/coronavirus-structure-vaccine-and-therapy-development)

Which of the following statements is **incorrect**?

A. Chemical analysis should reveal carbohydrate as a component of the coronavirus.
B. Treatment of the coronavirus with ethanol should denature the viral proteins, rendering the virus non-infectious.
C. The N protein is expected to have a net negative charge.
D. The E and M proteins are expected to have hydrophobic amino acids on the surfaces that face the envelope.

Answer C

Explanation

A. Chemical analysis should reveal carbohydrate as a component of the coronavirus.	✖	This is **incorrect**. The viral genome is a nucleic acid (RNA) that should contain ribose which is a carbohydrate. The proteins on the surface are glycosylated as well, thus contains carbohydrate.
B. Treatment of the coronavirus with ethanol should destroy lipid-rich membrane and denature the viral proteins, rendering the virus non-infectious.	✖	This is **incorrect**. Alcohol should be able to denature the proteins. This is the scientific reasoning behind using alcohol as a disinfectant.
C. The N protein is expected to have a net negative charge.	✔	This is **correct**. The genome is a nucleic acid that is negatively charged because of the phosphate groups in the backbone. Proteins that interact with nucleic acid are expected to have the opposite charge (net positive charge). In fact, the pI of the SARS-CoV-2 N protein is 10, thus it is positively charged at physiological pH.
D. The E and M proteins are expected to have hydrophobic amino acids on the surfaces that face the envelope.	✖	This is **incorrect**. The E and M proteins reside in the envelope which is derived from the cell membrane, thus they are expected to have hydrophobic exteriors.

Reference

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 398-402.

24. A person is sick from the COVID-19 virus. What kind of immunity does this person gain due to the infection and then retain after recovery?

A. Active immunity, innate immunity
B. Active immunity, acquired immunity
C. Passive immunity, innate immunity
D. Passive immunity, acquired immunity

Answer B. Active immunity, acquired immunity

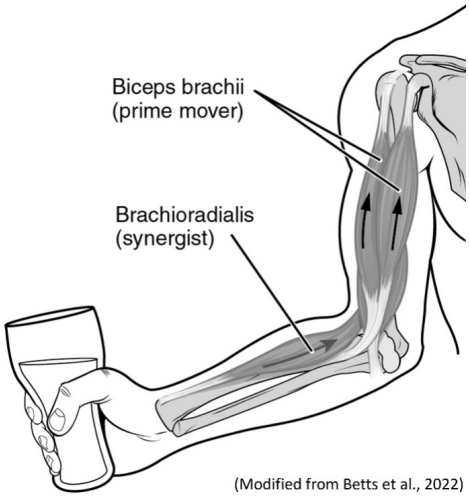
Explanation

A. Active immunity, innate immunity	✖	This is **incorrect**.
B. Active immunity, acquired immunity	✔	This is **correct**. Active immunity results when exposure to the pathogen (COVID-19 virus) directly triggers the immune system to produce the specific defense that is mediated by B cells and T cells to resist this pathogen. Acquired immunity is not present at birth. When a person's immune system encounters pathogens and recognizes antigens, it learns to attack each antigen and begin to develop a memory for that antigen.
C. Passive immunity, innate immunity	✖	This is **incorrect**. Passive immunity is a temporary adaptive immunity conferred by the transfer of antibodies from an immune individual to a non-immune one. Innate immunity is present at birth and does not have to be learned through exposure to a pathogen. It provides an immediate response to pathogens. Unlike acquired immunity, it has no memory of the encounters, does not remember specific antigens, and does not provide any ongoing protection against future infection.
D. Passive immunity, acquired immunity	✖	This is **incorrect**.

Reference

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 968-970.

25. The figure below shows the biceps brachii, which is a muscle that flexes the lower arm. The arrows indicate the tension force acting on the lower arm bone.



Consider the following statements:

I. Biceps brachii can be voluntarily controlled.
II. The muscle cell of the biceps brachii must have a striated appearance with multiple nuclei.
III. The neurotransmitter released by the motor neurons involved in contraction of biceps brachii is glutamate.

Which statements (I–III) are correct?

A. I only
B. II only
C. I and II
D. I and III

Answer C. I and II

Explanation

A. I only	✖	I only is **incorrect**.
B. II only	✖	II only is **incorrect**.
C. I and II	✔	I is **correct**. Biceps brachii is a skeletal muscle (i.e., attaching to a bone) that can be voluntarily controlled from motor cortex. II is **correct**. Skeletal muscle cell has striation and many nuclei.
D. I and III	✖	III is **incorrect**. Motor neuron releases acetylcholine to control skeletal muscle contraction.

Reference

Betts, J. G., Young, K. A., Wise, J. A., Johnson, E., Poe, B., Kruse, D. H., Korol, O., Johnson, J. E., Womble, M., & DeSaix, P. (2022). *Anatomy and Physiology 2e*. OpenStax. https://openstax.org/books/anatomy-and-physiology-2e/pages/10-2-skeletal-muscle

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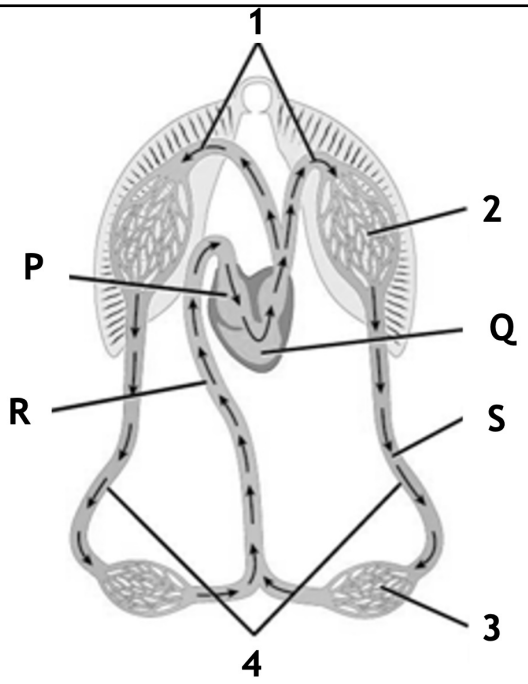
26. The diagram shows blood circulation in a fish. (1: gill circulation, 2: gill capillaries, 3: body capillaries, 4: systemic circulation)



(Modified from Betts et al., 2022)

Which of the following statements are correct?

I. P is a ventricle of the heart.
II. Blood in Q is oxygenated.
III. R is a vein.
IV. Blood pressure in S is higher than in R.

A. I and II
B. I and IV
C. II and III
D. III and IV

Answer D. III and IV

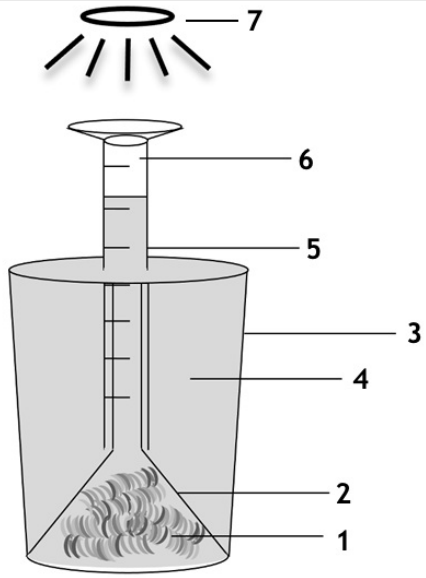
Explanation

A. I and II	▫	This is **incorrect**. P is an atrium of the heart (receiving blood from circulation). Blood in Q is deoxygenated blood (before gas is exchanged at the gill).
B. I and IV	▫	This is **incorrect**. P is an atrium of the heart (receiving blood from circulation). Blood pressure in S is higher than in R because blood flows from S to R.
C. II and III	▫	This is **incorrect**. Blood in Q is deoxygenated blood (before gas is exchanged at the gill). R is a vein (conducting blood to the heart).
D. III and IV	▫	This is **correct**. R is a vein (conducting blood to the heart). Blood pressure in S is higher than in R because blood flows from S to R.

Reference

Betts, J. G., Young, K. A., Wise, J. A., Johnson, E., Poe, B., Kruse, D. H., Korol, O., Johnson, J. E., Womble, M., & DeSaix, P. (2022). *Anatomy and Physiology 2e*. OpenStax. https://openstax.org/books/anatomy-and-physiology-2e/pages/40-1-overview-of-the-circulatory-system

27. Water thyme (*Hydrilla* sp.) plants (1) are placed inside an upturned funnel (2) in a beaker (3) containing pond water (4) with a small amount of $NaHCO_3$ added. The end of the funnel is covered with a measuring cylinder (5) in which air (6) was trapped. A light bulb (7) is used as a light source.



Consider the following statements:

I. If more $NaHCO_3$ is added to the water, more bubbles could be observed.
II. If the light is changed from white to blue light at the same intensity, more bubbles could be observed.
III. If the light is changed from white to green light at the same intensity, more bubbles could be observed.
IV. After three hours of the experiment, the air inside the cylinder is mostly carbon dioxide.

Which statements (I–IV) are correct?

A. I only
B. I and II
C. II and III
D. II and IV

Answer B. I and II

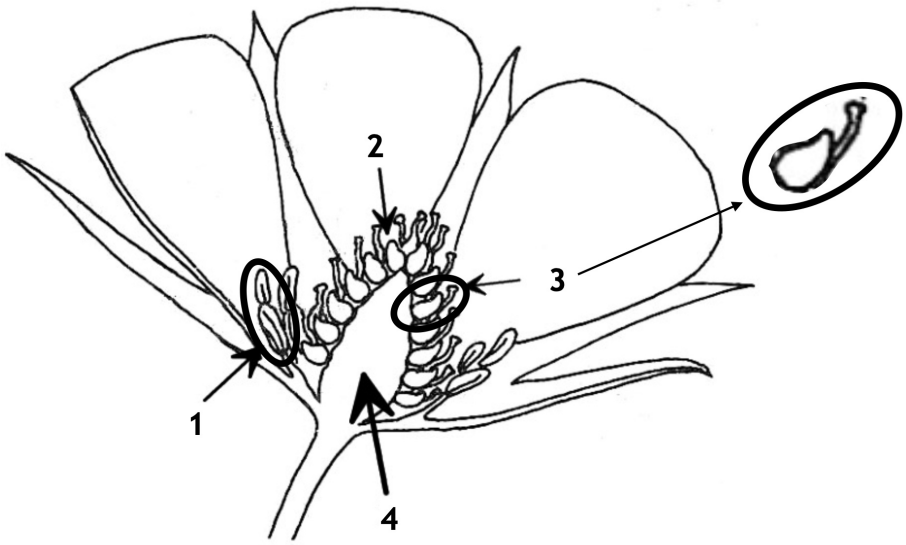
Explanation

A. I only	✖	I only is **incorrect**.
B. I and II	✔	I is **correct**. In this experiment, bicarbonate from $NaHCO_3$ is the primary source of CO_2 for photosynthesis. Thus, adding more $NaHCO_3$ would result in the increase of O_2 production, which could be observed as more bubbles. II is **correct**. White light mainly consists of blue, green and red light. The photosynthetic pigments of plants consist of chlorophylls and carotenoids which absorb white light (except green light). Blue light is absorbed by chlorophylls and has sufficient energy levels to activate photosystems. Therefore, if white light is changed to blue light, there should be more photosynthetic activity, resulting in more bubbles.
C. II and III	✖	III is **incorrect**. Green light is not absorbed by chlorophylls. Thus, there will be much fewer bubbles.
D. II and IV	✖	IV is **incorrect**. In photosynthesis, CO_2 is used, and O_2 is produced as a byproduct of the reaction. Thus, the air inside the cylinder is mostly O_2.

Reference

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 190 & 194.

28. According to their development, type of flower, and the number of ovaries, fruits are classified into 3 types: 1. simple fruit, which develops from a solitary flower with a single carpel or serveral fused carpels; 2. aggregate fruit, which develops from a solitary flower with more than one separate carpel, each forming a fruit; and 3. multiple fruit, which develops from an inflorescence with many dense florets, and the ovary walls are fused together into one fruit. If the flower shown in the diagram is fertilized, which type of fruit will be developed? (1: stamen, 2: carpel, 3: pistil, 4: receptacle)



(Modified from https://fruit.umn.edu/content/flowers-to-fruit)

A. A simple fruit
B. An aggregate fruit
C. A multiple fruit
D. A fruit with many seeds

Answer B. An aggregate fruit

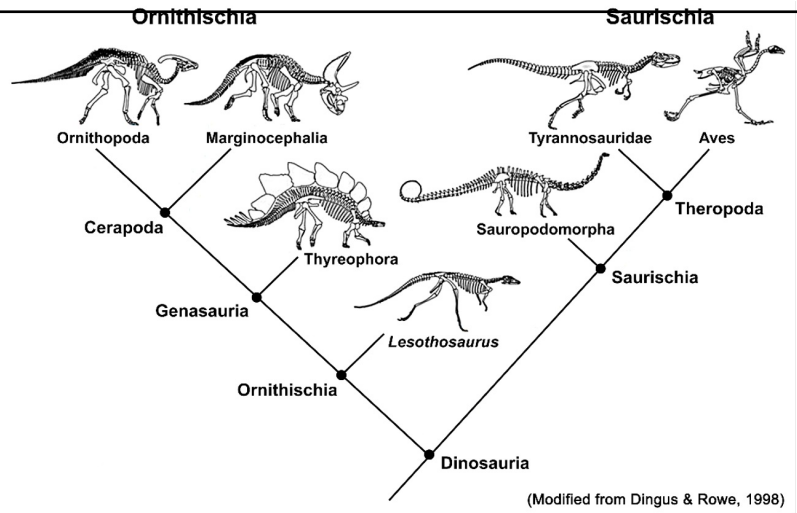
Explanation

A. A simple fruit	✖	This is **incorrect**. Simple fruit develops from a solitary flower with a single ovary, e.g. mango.
B. An aggregate fruit	✔	This is **correct**. The flower in this figure is a solitary flower with many ovaries on the same receptacle which will develop into aggregate fruit, e.g. strawberry.
C. A multiple fruit	✖	This is **incorrect**. Multiple fruit develops from inflorescence with many dense florets in the same inflorescence, e.g. pineapple.
D. A fruit with many seeds	✖	This is **incorrect**. When this flower undergoes fertilization, each fruit will consist of a single seed.

Reference

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 830-831.

29. Most of the dinosaurs are members of two lineages, namely Ornithischia and Saurischia. Ornithischia includes the bird-hipped dinosaurs, while Saurischia includes the lizard-hipped dinosaurs. The cladogram illustrates the relationships of these lineages. Modern birds were apparently descended from the saurischians; however, they possess hips similar to those of the relatively unrelated ornithischians.



Which of the following correctly explains the hip similarity in birds and ornithischians?

A. Adaptive radiation of the modern birds
B. Convergent evolution with the ornithischians
C. Divergent evolution with the ornithischians
D. Descent with modification from a common ancestor of the saurischians

Answer B. Convergent evolution with the ornithischians

Explanation

A. Adaptive radiation of the modern birds	✖	This is **incorrect**. Adaptive radiation is a process in which organisms diversify rapidly from an ancestral species into many new forms.
B. Convergent evolution with the ornithischians	✔	This is **correct**. Convergent evolution creates analogous structures that have similar form or function but were not present in the last common ancestor of those groups.
C. Divergent evolution with the ornithischians	✖	This is **incorrect**. Divergent evolution is the accumulation of differences between closely related populations within a species, sometimes leading to speciation.
D. Descent with modification from a common ancestor of the saurischians	✖	This is **incorrect**. Descent with modification is the process by which species accumulate differences from their ancestors as they adapt to different environments over time.

References

Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). *Campbell biology* (12th ed.). Pearson. pp. 553-572.

Dingus, L. & Rowe, T. (1998). The evolutionary map for dinosaurs. In The Mistaken Extinction: Dinosaur Evolution and the Origin of Birds (1st Ed.). W. H. Freeman Publisher, 332 pp.

30. One of the suggested solutions to reduce greenhouse gas (GHG) emissions and climate

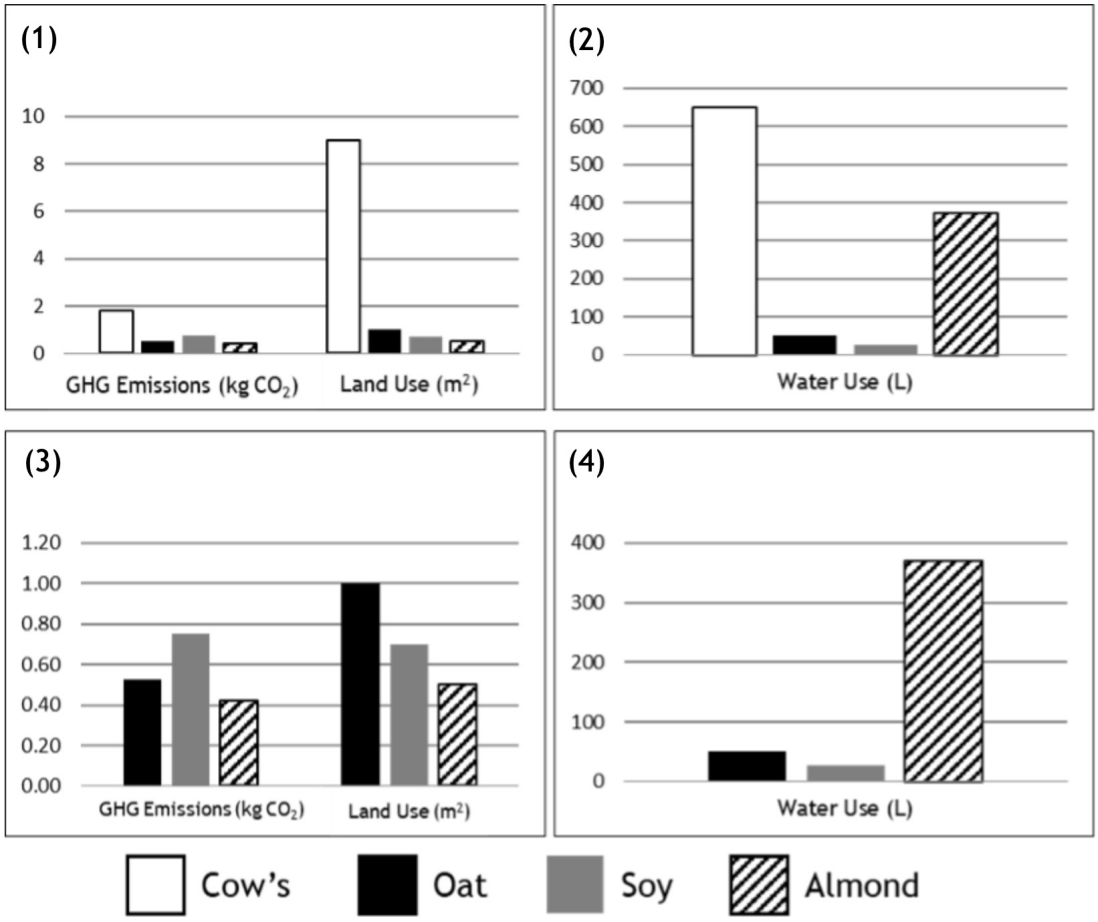
change for a more sustainable future is to find alternatives in our diets, such as switching to plant-based milk instead of cow's milk. But are they really more environmentally friendly? Growing the crops and the production processes of these goods are not without their impacts. The environmental resources that are required for, and the GHG emissions that result from, production are important considerations. The following graphs show the global average of GHG emissions (kg CO_2), land use (m^2) and water use (L) in the production of one liter of milk product.

Graphs: (1) GHG emissions and land use of all milk products

(2) Water use of all milk products

(3) GHG emissions and land use of plant-based milk products

(4) Water use of plant-based milk products



The width of the bars is not relevant in the analysis of the question.

Consider the proposed plant-based milk products' suitability as alternatives to cow's milk. Which of the following statements are supported by the data?

I. All of the proposed plant-based milk products are reasonable alternatives to cow's milk.
II. Considering all factors, soy milk is the best alternative to cow's milk.
III. Based on the percentage difference, almond milk is the worst alternative to cow's milk overall.
IV. Compared to oat milk, cow's milk is worse for the environment in terms of land use than it is in terms of water use.
V. Almond milk's water requirements make it unviable as an alternative to cow's milk.
VI. Oat milk is not the best alternative to cow's milk for any given factor.

A. I, II, and IV
B. I, III, and VI
C. II, III, and IV
D. II, V, and VI

Answer B. I, III, and VI

Explanation

A. I, II, and IV	✖	II is **incorrect**. Soy milk is best only in terms of water use, but not for either GHG emissions or land use. IV is **incorrect**. Compared to oat milk, cow's milk is nine times worse in terms of land use, and 13 times worse in terms of water use.
B. I, III, and VI	✔	I is **correct**. Compared to cow's milk, all three plant-based milk products are associated with lower GHG emissions, land use, and water use. III is **correct**. Based on the percentage difference, although almond milk is best in terms of GHG emissions (just under half of soy) and land use (about half of oat), its extremely high water requirement of more than seven times that of oat milk negates the other benefits. VI is **correct**. None of oat milk's impacts is the lowest.
C. II, III, and IV	✖	II is **incorrect**. Soy milk is best only in terms of water use, but not for either GHG emissions or land use. IV is **incorrect**. Compared to oat milk, cow's milk is nine times worse in terms of land use, and 13 times worse in terms of water use.
D. II, V, and VI	✖	II is **incorrect**. Soy milk is best only in terms of water use, but not for either GHG emissions or land use. V is **incorrect**. All of almond milk's impacts are still lower than those of cow's milk.

Reference

Kanyama, A. C., Hedin, B., & Katzeff, C. (2021). Differences in environmental impact between plant-based alternatives to dairy and dairy products: A systematic literature review. *Sustainability*, *13*, 12599. https://doi.org/10.3390/su132212599