11th International Junior Science Olympiad

Theoretical Competition

December 6, 2014

(Answer Sheet)

FILL IN THE FOLLOWING INFORMATION

FIRST NAME	
LAST NAME	
COUNTRY	
CODE	
SIGNATURE	

PROBLEM 1

1.1.1. Fill in Table 3 in the Answer sheet with the information related to each community.

Community	Species Richness (S)	Total number of individuals (N)	Name of dominant species	Abundance of dominant species	J
Sample 1: Community revegetated with Larrea	**15** (a)[0,20]	***5 450*** (b)[0,20]	**Erodium cicatarium** (c)[0,20]	**750** (d)[0,20]	**0.95** (e)[0.45]
Sample 2: Community left to natural succession	**15** (f)[0,20]	***2 265*** (g)[0,20]	**Aristida mendocina** (h)[0,20]	**1000** (i)[0,20]	**0.72** (j)[0.45]

Table Nº 3

total [2.50]

1.1.2. Indicate which community has a greater biological diversity.

Answer: Sample 1

(a) [0.25]

1.1.3 Mark true (T) or false (F) appropriately for each explanation shown on the answer sheet, in order to justify the answer given in 1.1.2.

A. After ten years, the community revegetated with jarilla and the community left to natural succession have a wide difference in species richness, related to *Larrea spp.*'s facilitating effect.	**F (a) [0.10]**
B. The presence of *Larrea* in sample 1 increased the abundance of shrubs and herbaceous forms. This could indicate that *Larrea* favors the settling of other species, augmenting the evenness of this community.	**T (b) [0.10]**
C. The favoring effects are indicating that the revegetated community (sample 1) presents less distribution of forms of life than the community left to natural succession.	**F (c) [0.10]**

total [0.30]

1.2. Calculate the total surface area of the region. Express the final result in square hectometers (hectares).

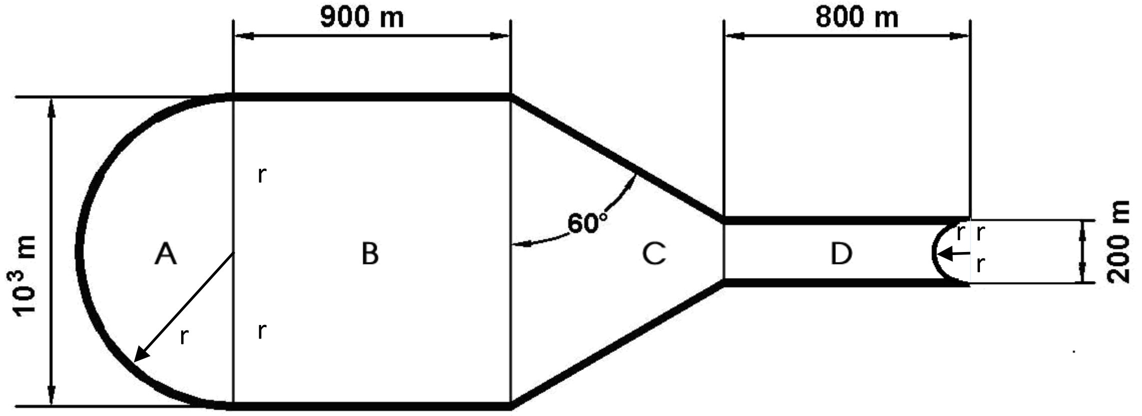


Figure Nº 4: Schematic representation of the region to be revegetated.

RESOLUTION:

RESOLUTION:

10^3 m= 1000m

Total surface area = A+ B+ C+ D

<u>A</u>:

Surface area of half-circle: $\frac{\pi . r^2}{2}$

Radius: $\frac{10^3}{2}$ m = 500m

A= $\frac{\pi(\frac{10^3}{2})^2}{2} = 3.93x10^5$

A= $3.93x10^5$ m^2 **(a) [0.4]**

<u>B</u>:

Surface area of a rectangle: 900 m x10^3 m= $9x10^5$ m^2

B= $9x10^5$ m^2 **(b) [0.4]**

<u>C</u>:

Surface area of trapezoid: $(\frac{majorbase + minorbase}{2}).height$

Major base: 1000m

Minor base: 200m

Height:

They can use sexagecimal degrees or radians.

Using radians:

h= $\tan\left(\frac{\pi}{3}\right)\cdot\left(\frac{10^{3}-2\cdot 10^{2}}{2}\right)=692.82$

Using sexagecimal degrees:

h= $t\ \ a6\ {}^{\circ}n\ 0\ (\ (\frac{1^{3}-02.1^{2}\ 0}{2})=6\ \ .89$

Value of height: 692.82 m

C= $\frac{(10^{3}+2x10^{2})}{2}692.82=4.16x10^{5}$

C= 4.16x10^{5} m^{2} **(c) [0.6]**

<u>D</u>:

Surface area of a rectangle - Surface area of half-circle=

=(800 m x 200 m)- ($\frac{\pi .100^{2}}{2}$)=

=1.6x10^{5} m^{2} - 1.57x10^{4} m^{2}
= 1.44x10^{5} m^{2}

D = 1.44x10^{5} m^{2} **(d) [0.4]**

Total Surface area = A+ B+ C+ D

=3.93x10^{5} m^{2}+9x10^{5} m^{2}+4.16x10^{5} m^{2}+1.44x10^{5} m^{2}

Total Surface area = **1.85x10^{6} m^{2}**

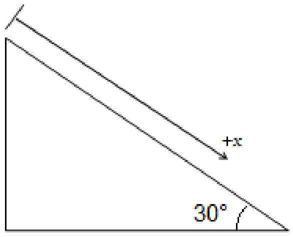
ANSWER: **Total Surface area =1.85x10^{6} m^{2}**

(e) [0.1]

total [1.9]

1.3.1. Find the velocity of the rock when it passes by point II.

RESOLUTION: The problem is essentially dynamics in one dimension, taking the movement axis *x* parallel to the slope with its positive sense "down the slope" (see figure below). Thus,



A. Summing forces in *x,* and applying Newton's 2nd:

$$\Sigma F_x = ma_x$$

$$F_{gravity(x)} + F_{friction} = ma_x$$

$$mg \text{ sen } 30° - \mu mg \cos 30° = ma_x$$

(where μ=0.46 is the coefficient of kinetic friction).

(a) [0.40]

B. Solving for a_x, and computing (note that there's no need to know the mass of the rock):

$$a_x = g \text{ sen } 30° - \mu g \cos 30°$$

$a_x = 9.81 m/s^2 \text{ sen } 30° - 0.46\ 9.81 m/s^2 \cos 30° = 0.99 m/s^2$ ó $1 m/s^2$ (b) [0.40]

C. Finally, as this acceleration is constant, and the displacement Δx and the velocity V_I are given, one can use

$V_{II}^2 = V_I^2 + 2\Delta x a_x$

$V_{II} = \sqrt{(2\Delta x a_x + V_I^2)} = \sqrt{[2(50m)(0.99m/s^2)+(10m/s)^2]} = 14.10 m/s$

(c) [0.40]

ANSWER: $\mathbf{V_{II} = 14.1\ m.s^{-1}}$

(d) [0.10]

total [1.30]

1.3.2. Find the kinetic friction coefficient of this stretch, assuming it is constant throughout it.

RESOLUTION:

i) Find the acceleration a_x from: $V_{III}^2 = V_{II}^2 + 2\Delta x a_x$

$2\Delta x a_x = (V_{III}^2 - V_{II}^2)$

$a_x = (V_{III}^2 - V_{II}^2)/2\Delta x$

$a_x = [0 - (14.1 m/s)^2]/(2\ 200m) = -0.5 m/s^2$ ó $-0.49 m/s^2$ (a) [0.40]

ii) Sum forces in *x* (same as previous problem):

$\Sigma F_x = ma_x$

mg sen 30° - µmg cos 30° = ma_x

g sen 30° - µg cos 30° = a_x

(b) [0.40]

iii) Finally, solving for µ and using the value of a_x found in i):

µ = (g sen 30° - a_x)/g cos 30°

µ = [(9.81m/s^2) sen 30° - (-0.5m/s^2)] / (9.8m/s^2 cos 30°)

(c) [0.40]

ANSWER: **µ = 0.64 o : µ = 0.63**

(d) [0.10]

total [1.30]

1.4.1. Determine which nutrient you would choose as a guide for establishing the amount of fertilizer to be used.

ANSWER:

Phosphorus (P)

total (a) [0.20]

1.4.2 Compute how many kilograms of fertilizer must be added per square meter of terrain. Round results using two decimal after the unit.

RESOLUTION USING DIMENSIONAL ANALYSIS:

The amount of P to add is the difference: 8.12-1.00= 7.12 mg.

(a) **[0.20]**

To find the amount of fertilizer per ha, one has to find the mass of soil (kg) per hm^2:

Then, "surface area of site" X "depth" X "density":

$$\frac{kg\ soil}{m^2} = 30cm\,\frac{1m}{100cm}\,\frac{1630kg\ soil}{m^3} = 489\,\frac{kg}{m^2}$$

(b) **[0.20]**

$$\frac{7.12mg\ \boldsymbol{P}}{kg\ \boldsymbol{soil}}\,\frac{1g}{1000mg}\,\frac{142g\ \boldsymbol{P_2O_5}}{62g\ \boldsymbol{P}}\,\frac{100g\ \boldsymbol{fertilizer}}{15g\ \boldsymbol{P_2O_5}} = 0.109\,\frac{g\ \boldsymbol{fertilizer}}{kg\ \boldsymbol{soil}}$$

(c) [0.20]

(FROM NOW, 0.11g OF FERTILIZER)

$$\frac{kg\ \boldsymbol{fertilizer}}{m^2} = \frac{0.11g\ \boldsymbol{fertilizer}}{kg\ \boldsymbol{soil}} \frac{1kg\ \boldsymbol{fertilizer}}{1000g\ \boldsymbol{fertilizer}} 489 \frac{kg\ \boldsymbol{soil}}{m^2} = 0.05 \frac{kg\ \boldsymbol{fertilizer}}{Hm^2}$$

(d) [0.20]

Puede ser 0.053 kg/m2 si usara cifras significativas y 0.109

RESOLUTION BY RULE OF THREE (or SIMPLE PROPORTIONS):

The amount of P to add is: 8.12-1.00= 7.12 mg de P

To find the amount of fertilizer per Hm^2, one has to find the mass of soil (kg) per hm^2:

Then, "surface area of site" X "depth" X "density":

Then:

1000 mg ———— 1 g

7.12 mg ———— x= 7.12×10^{-3} g P/Kg soil

62 g P ———— 142 g P_2O_5

7.12×10^{-3} g P ———— x= 1.6×10^{-2} P_2O_5

15 g P_2O_5 ———— 100 g fertilizer

0.016 g fertilizer ———— x= 0.109 g fertilizer /kg soil (FROM NOW: 0.11g FERTILIZER/kg SOIL)

1 kg soil ———— 1.1×10^{-4}kg fertilizer

4890000 kg hm^{-2}soil ———— x= 537.90 kg fertilizer hm^{-2}soil

ANSWER: 0.054 kg of fertilizer per square meter

(e) **[0.10]**

total [0.90]

1.4.3. Determine the concentration of hydroxide ions $(OH)^{1-}$ responsible for the pH value measured in the disturbed soil shown in Table 4.

RESOLUTION USING DIMENSIONAL ANALYSIS:

pH=7.54 Then, 14 –pH=pOH=6.46 (a) [0.30]

$[OH^-] = 10^{-6.46} = 3.47 \times 10^{-7}$ mol/l	(b) [0.30]
ANSWER: 3.47×10^{-7} mol/l (c) [0.10]	

total [0.70]

1.4.4. Indicate which of the pH indicators shown in Table 5 you would choose to determine qualitatively the disturbed soil pH, and what color the chosen indicator would take. Write the indicator and the color using the code in parentheses).

ANSWER:

Indicator: **BB** (a) [0.15]

Color: **B** (b) [0.15]

total [0.30]

1.4.5. Write the balanced chemical equation for the total ionization reaction of Na_2CO_3 in water.

ANSWER:

$$\mathbf{Na_2CO_3 + H_2O \longrightarrow 2Na^+ + CO_3^{2-} + H_2O}$$ **(a) [0.30]**

Pueden escribir el agua sobre la flecha y es valido o no escribirla

1.4.6. Write the balanced ionic hydrolysis equation that justifies the pH elevation in the soil due to the carbonate ion.

ANSWER:

$$\mathbf{CO_3^{2-} + H_2O \rightleftarrows CO_3H^- + OH^-}$$ **(a) [0.30]**

1.5.1. Indicate which one illustration best expresses the description given in 1.5.

ANSWER: **B**

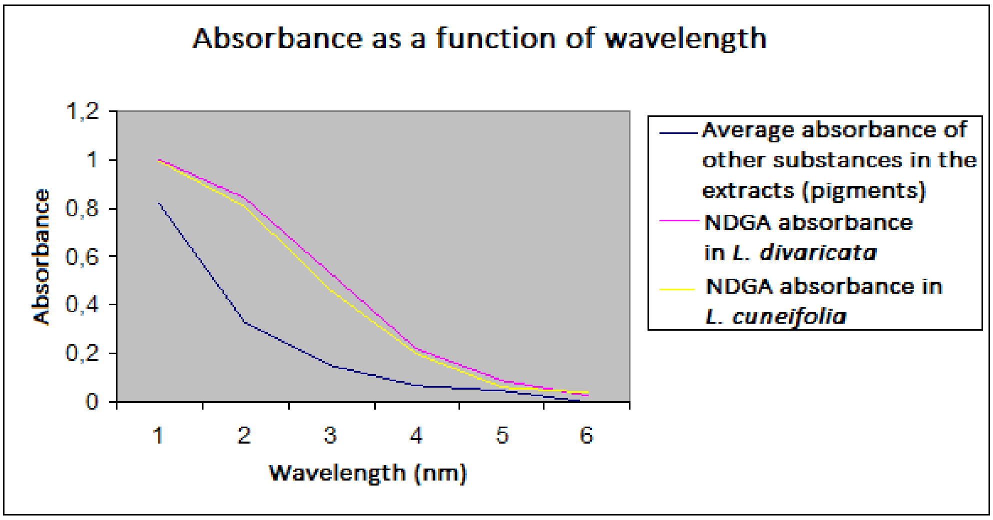
total (a) [0.35]

1.5.2. Select from the following options the statement that provides the reason to the answer to 1.5.1.

ANSWER: **C**

total (a) [0.30]

1.6.1. Draw a Cartesian graph of comparative lines for absorbance as a function of wavelength for the three samples, based on Table 6. Use different colors for each type of absorbance line.



(a) [0.25]

(b) [0.25]

(c) [0.25]

(d) [0.15]

total [0.90]

1.6.2. Using the information given in Table 6, indicate the wavelength that is needed to best distinguish NDGA from other substances.

ANSWER: **450nm**

total (a) [0.20]

1.6.3. Calculate the NDGA concentration (mg L^{-1}) in each extract. Consider the extract was purified from other substances.

RESOLUTION:
For A:
Applying A = C . ε. L.
Solving for C: $C = \frac{A}{\epsilon L}$

$C = \frac{0.47\ M\ cm}{8\ 920\ 1cm} = 5.26\ x\ 10^{-5} M$

Then:
BY DIMENSIONAL ANALYSIS :

$5.26\ x\ 10^{-5} \frac{mol}{l} \frac{302g}{mol} \frac{1000mg}{1g} = 15.88 \frac{mg}{l}$ (a) [0.35]

BY RULE OF THREE:

1mol ———————— 302g
5.26 x 10^{-5} mol ———————— x= 0.01588g

1g ———————— 1000mg
0.0158g ———————— x= 15.88mg

For B:

Applying A = C . ε. L. Solving for C: $C = \frac{A}{\varepsilon L}$

$$C = \frac{0.52\ M\ cm}{8\ 920\ 1cm} = 5.83\ x\ 10^{-5} M$$

Then, BY DIMENSIONAL ANALYSIS:

$$5.83x\ 10^{-5}\frac{mol}{l}\frac{302g}{mol}\frac{1000mg}{1g} = 17.61\frac{mg}{l}$$ (b) [0.35]

BY RULE OF THREE

1 mol ———————— 302 g

5.83 x 10^{-5} mol ———————— x= 0.0176g

1g ———————— 1000 mg

0.0176 g ———————— x= 17.61 mg

ANSWER: A=15.88 mg (c) [0.10]
; B=17.61 mg (d) [0.10]

total [0.90]

1.6.4. Using the information in Table 6 and the values for each absorbance, indicate the species corresponding to each extract.

ANSWER:

Extract A: ***L. cuneifolia*** **(a) [0.10]**
Extract B: ***L. divaricata*** **(b) [0.10]**

total [0.20]

1.6.5. Determine the mass of fresh *L. divaricata* leaves that you need considering that fresh leaves have a moisture content of 8% w/w (water density at 20°C is 1 g cm^{-3}).

RESOLUTION

BY DIMENSIONAL ANALYSIS:

$$500ml\,\frac{0.2g\ \boldsymbol{NDGA}}{100ml}\,\frac{100g\ \boldsymbol{dry\ leaves}}{7g\ \boldsymbol{NDGA}}\,\frac{100g\ \boldsymbol{fresh\ leaves}}{92g\ \boldsymbol{dry\ leaves}} = 15.43g\ \boldsymbol{fresh\ leaves}$$ **(a) [0.60]**

Los rusos y Zimbwe lo hacen de otra manera y les da 15.53, es aceptable y lo hemos conversado

BY RULE OF THREE.

100 ml ________ 0,2 g NDGA
500 ml ___________ x= 1 g NDGA

7 g NDGA ____________ 100g dry leaves
1 g NDGA ____________ x= 14.29 g dry leaves

92 g dry leaves__________ 100g fresh leaves
14.29 g dry leaves _______ x= 15.43 g fresh leaves

ANSWER: 15.43 g of fresh leaves

(b)[0.10]

total [0.70]

PROBLEM 2

2.1.1. Write the chemical reactions needed to obtain the acids derived from SO_3 and CO_2 when combined with water.

Answer:

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$ **(a) [0.35]**
$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$ **(b) [0.35]**

total [0.70]

2.1.2. The unbalanced formation reaction of nitric acid in acid rain is:

$$NO_2\,(g) + H_2O\,(l) \rightarrow HNO_3\,(aq) + HNO_2\,(aq)$$

Write the half-reactions and the balanced equation.

RESOLUTION:

$NO_2(g) + H_2O(l) \rightarrow NO_3^-(aq) + 2H^+(aq) + 1e^-$ **(a) [0.35]**

$NO_2(g) + H^+ + 1e^- \rightarrow HNO_2(aq)$ **(b) [0.35]**

$2NO_2\,(g) + H_2O(l) \rightarrow HNO_3\,(aq) + HNO_2\,(aq)$ **(c) [0.30]**

Total [1.00]

2.2.1. Determine the solubility in moles per liter of aluminum hydroxide ($Al(OH)_3$) in the lake water which has a pH value of 5.2, knowing that the Ksp (solubility product) value is $5x10^{-33}$.

RESOLUTION

$$\mathrm{pH} + \mathrm{pOH} = 14$$
$$\mathrm{pOH} = 14 - 5.2$$
$$\mathrm{pOH} = 8.8$$
$$[\mathrm{OH}^-] = 10^{-8.8}$$
$$[\mathrm{OH}^-] = 1\mathrm{x}10^{-9}\ \mathrm{mol/L}$$

(a) [0.25]

$$\mathrm{Kps} = [\mathrm{Al}^{3+}] * [\mathrm{OH}^-]^3$$
$$\frac{\mathrm{Kps}}{[\mathrm{OH}^-]^3} = [\mathrm{Al}^{3+}]$$
$$[\mathrm{Al}^{3+}] = \frac{5\ \mathrm{x}\ 10^{-33}}{[1\ \mathrm{x}\ 10^{-9}]^3}$$

(b) [0.4]

Answer: $\boxed{[\mathrm{Al}^{3+}] = 1\ \mathrm{x}\ 10^{-6}\mathrm{mol/L}}$ (c) [0.10]

total [0.75]

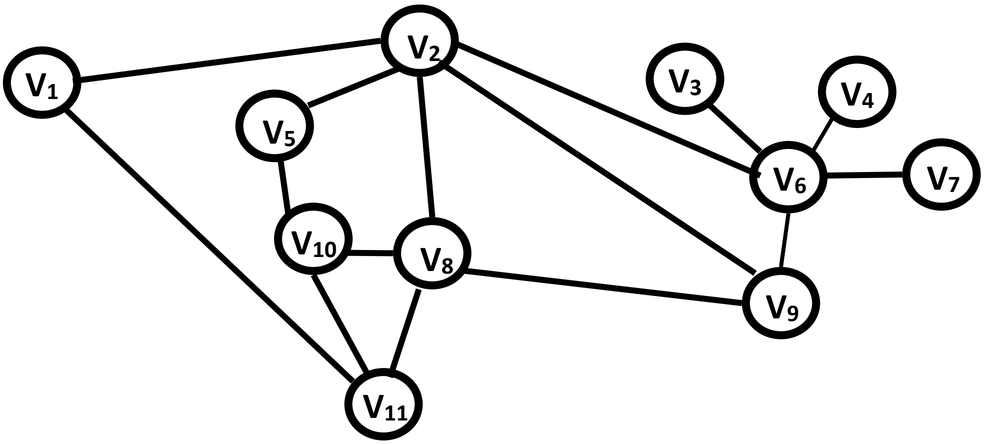


Figure 8: Water piping network

2.3.1. Determine the maximum number of pipes that can be removed without interrupting the water supplyin every distribution point.

Answer: **5**

total [0.20]

2.4.1. Compute the average value of lead in blood for each sample.Indicate which of them, if any, is above the toxicity levels, writing an A for adults, a C for children, and a B for both

Answer:	
Adults' sample mean: 0.058 mg/100ml	(a) [0.10]
Children's sample mean: 0.0076 mg/100ml	(b) [0.10]
Sample/s above the toxicity levels:	**(c) [0.10]**

total [0.30]

2.5.1. Calculate Earth's equilibrium temperature without the absorption of the atmosphere (Figure 9a). Express your results in K and °C.

The intensity I (W m^{-2}) radiated by a black body follows Stefan-Boltzmann's Law:

$$I = \sigma T^4, \quad \text{where } \sigma = 5{,}67 \times 10^{-8} \text{W m}^{-2}\text{K}^{-4}$$

Assume that the Earth radiates energy as a black body.

RESOLUTION:

$$0.7 \cdot I_0 = \sigma \cdot (T_{earth})^4$$

$$T_{earth} = \left(\frac{0.7 \cdot 341 \mathrm{W} \cdot m^{-2}}{5{,}67x10^{-8} W \cdot m^{-2} \cdot K^{-4}} \right)^{1/4}$$

$$T_{earth} = 254.7\mathrm{K} = -18.45°C$$

(a) [0.50]

Answer:

254.7 K ; -18.45 °C

(b) [0.10]

total [0.60]

2.5.2. Find the equilibrium temperature of the Earth with the atmosphere (Figure 9b), assuming that the atmosphere absorbs all the radiation emitted by the surface, and reemits it back to both the Earth and Space in equal proportions. Start out with intensity balance on the Earth surface and on the atmosphere.

Hint:
Assume that the atmosphere only absorbs energy from the Earth surface, and that both emit energy as a black body.

RESOLUTION:

Energy balance for the Earth:
From the Sun + From the atmosphere= Emitted

$$0.7 \cdot I_0 + \sigma \cdot (T_{atmosphere})^4 = \sigma \cdot (T_{earth})^4 \quad (eq.1)$$

(a) [0.50]

Energy balance for the atmosphere:
From the Earth's surface = Emitted to space and back to surface

$$\sigma \cdot (T_{earth})^4 = 2 \cdot \sigma \cdot (T_{atmosphere})^4$$

$$(T_{atmosphere})^4 = 1/2 \cdot (T_{earth})^4 \quad (eq.2)$$

Inserting (2) in (1)

$$0.7\cdot \quad 341\mathrm{W}\cdot m^{-2} \quad + \quad \frac{\sigma\cdot(T_{earth})^4}{2} \quad = \quad \sigma\cdot(T_{earth})^4$$

$$T_{earth} \quad = \quad \left(\frac{2\cdot 0.7\cdot 341\mathrm{W}\cdot m^{-2}}{5{,}67x10^{-8}W\cdot m^{-2}\cdot K^{-4}}\right)^{1/4}$$ (b) [0.50]

$$T_{earth} \quad = \quad 303\mathrm{K} = 29.85°\mathrm{C} \text{ó } 29.8°\mathrm{C}$$

Answer: 29.85°C = 303 K

(c) [0.10]

total [1.10]

2.6.1. In this context, calculate the minimum amount of energy needed to completely melt a block of 10000kg of ice, initially at -10°C.

Thermodynamic constants:

Specific heat capacity of Ice: c = 2.093 $Jg^{-1}K^{-1}$

Latent heat of ice fusion: l = 333.7 J g^{-1}

RESOLUTION:

First, ice has to be heated from -10°C to 0°C (melting temperature)

$$E_1 \quad = \quad m\cdot c\cdot \Delta T$$

$$E_1 \quad = \quad 10x10^6 g\cdot 2.093J\cdot g^{-1}\cdot K^{-1}\cdot 10\mathrm{K}$$ (a) [0.40]

$$E_1 \quad = \quad 2x10^8 J$$

Once the ice is at 0°C , it is melted:

$$E_2 \quad = \quad m\cdot l$$

$$E_2 \quad = \quad 10x10^6 g\cdot 333.7\mathrm{J}\cdot g^{-1}$$ (b) [0.40]

$$E_2 \quad = \quad 3.34x10^9 J$$

The total energy is the sum of these two values:

$E_{total} = E_1 + E_2 = 3.54x10^9J$ ó $3.55x10^9J$ (c) [0.20]

Answer: $E_{total} = E_1 + E_2 = 3.54x10^9J$

(d)[0.10]

total [1.10]

PROBLEM 3

3.1.1. Based on the information shown on Table A and Table B, mark with a cross (X) on Table A the secretory structure which produces the enzyme involved in digesting the starch that is present in the slice of toast. Then, use the corresponding number given to the enzyme shown on Table B, to match the Structure where this enzyme is produced.
Hint: the same enzyme may be produced by more than one structure.

Table A

STRUCTURE	SECRETORY STRUCTURE INVOLVED IN THE DIGESTION OF STARCH	ENZYME
Liver		
Stomach		
Salivary Glands	X (a) [0.15]	3 (b) [0.15]
Large intestine		
Pancreas	X (c) [0.15]	3 (d) [0.15]
Esophagus		
Small Intestine	X (e) [0.15]	2 (f) [0.15]

Table B

1	Phospholipase
2	Maltase
3	Amylase
4	Lipase
5	Glucosidase
6	Sucrase

total [0.90]

3.1.2. Fill in Table C (indicated on the Answer Sheet) which shows enzymatic reactions. Write the corresponding letter of the enzyme in the green box and the corresponding number for the products in the blue boxes (each number may be used more than once).

ENZYMES		PRODUCTS	
A	Creatin kinase	1	Maltose
B	Amylase	2	Glucose
C	Lactase	3	Fructose
D	Glucosidase	4	Lactose
E	Sucrase	5	Galactose
F	Maltase	6	Saccharose (sucrose)

Table C

starch	B (a) [0.15]	1 (b) [0.15]		
maltose	F (c) [0.15]	2 (d) [0.15]	+	2 (e) [0.15]
lactose	C(f) [0.15]	2 (g) [0.15]	+	5 (a) [0.15]
saccharose (sucrose)	E (i) [0.15]	2 (j) [0.15]	+	3 (k) [0.15]

Total [1.65]

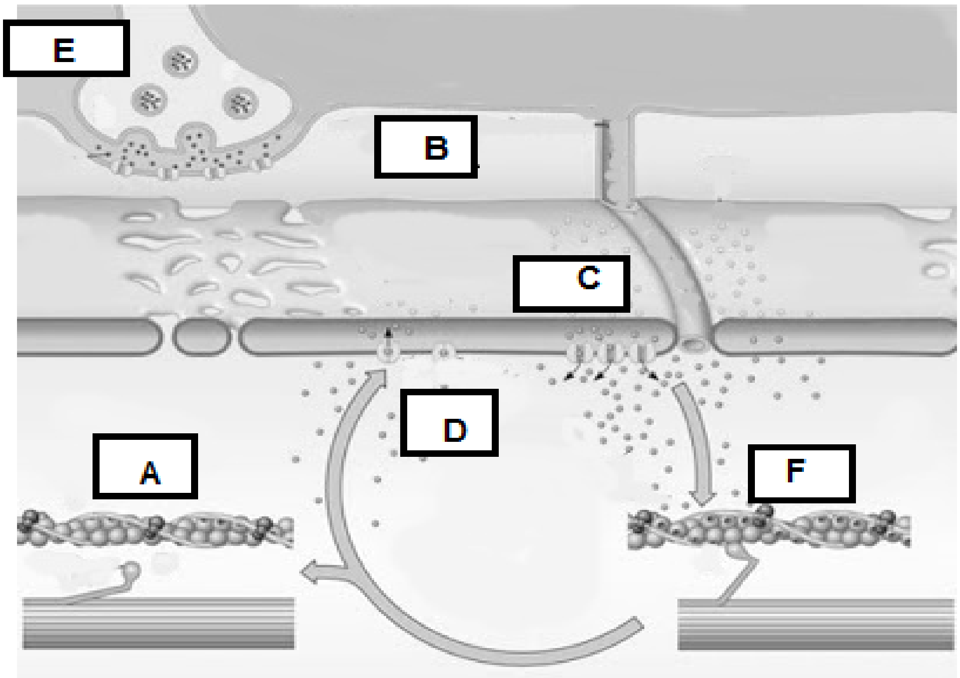
3.2.1 Table D shows muscular contraction processes. Complete Table E (indicated in Answer Sheet), indicating the letter of the process in the order in which they occur.

Table D: Processes of muscle contraction
A. ATP is hydrolyzed to ADP + Pi (inorganic phosphorus) and the myosin head is separated from the active site.
B. Acetylcholine acts on a local area of the sarcolemma to open multiple membrane protein channels. This allows the entry of large amounts of sodium ions into the sarcolemma, which initiates an action potential in the muscle fiber.
C. The action potential depolarizes the sarcolemma. The release of Ca^{++} ions from the sarcoplasmic reticulum occurs.
D. Ca^{++} ions are pumped back into the sarcoplasmic reticulum, where they remain until the arrival of a new action potential to the muscle.
E. An action potential reaches the neuromuscular junction (synapse) of a motor neuron and a muscle, acetylcholine is released from the axon terminal.
F. Ca^{++} ions initiate attractive forces between the actin and myosin. Filaments of myosin and actin are arranged next to each other within the sarcomere so that that they can interact in an organized fashion resulting in muscle contraction. During contraction, myosin heads bind actin and pull the filaments in towards the center.

Tabla E	
ORDER	CORRESPONDING LETTER
1	E (a) [0.2]
2	B (b) [0.2]
3	C (c) [0.2]
4	F (d) [0.2]
5	A (e) [0.2]
6	D (f) [0.2]

total [1.2]

3.2.2 Figure 11 represents muscle contraction. Write the letter corresponding to each process in the space provided.



E (a) [0.2]

B (b) [0.2]

C (c) [0.2]

D (d) [0.2]

A (e) [0.2]

F (f) [0.2] total [1.2]

3.3.1. Calculate the minimum amount of "engines" a muscle should utilize in lifting a mass of 50 kg. (Acceleration of gravity: 9.81 m s^{-2})

RESOLUTION:
P = m.g = 50kg 9.81m/s^2 = 490.5N (a) [0.15]

The number of myosin engines will be: 490N/5x10^{-12}N = 9.81x10^{13} engines (b) [0.15]

ANSWER: 9.81x10^{13} engines (c) [0.10]

total [0.40]

3.3.2. Calculate the power developed by the myosin engine measured in J s^{-1}.

RESOLUTION:

Power = Force x Velocity (a) [0.15]

Power= $5x10^{-12}$N . $11x10^{-9}$m.s^{-1}

Power= $5.5x10^{-20}$J.s^{-1} (b) [0.15]

ANSWER: $5.5x10^{-20}$ J s^{-1}

[0.10]

total [0.40]

3.4.1. If the food ingested at breakfast by the athlete is equivalent to 90 g of glucose, calculate the mass of carbon dioxide (CO_2) produced as a result of complete combustion. (Relative atomic mass C= 12; O=16; H=1).

RESOLUTION:

$C_6H_{12}O_{6(S)} + 6\ O_{2\ (g)} \longrightarrow 6\ CO_{2\ (g)} + 6\ H_2O_{(l)}$ (a) [0.20]

Mass of CO_2=

90 g glucosa $\frac{1}{180}\frac{mol}{g}\frac{glucose}{glucose}\frac{6}{1}\frac{mol}{mol}\frac{CO_2}{glucose}\frac{44gCO_2}{molCO_2}$ =132 g CO_2 (b)[0.30]

RULE OF THREE:

1 mol glucose ———— 6 mol CO_2
5 mol glucose ———— x= 3 mol CO_2

1 mol CO_2 ———— 44 g
3 mol CO_2 ———— x= 132 g CO_2

ANSWER: 132 g CO_2

(c) [0.10]

total [0.60]

3.4.2. Calculate the number of oxygen atoms in 90 g of glucose molecules.

RESOLUTION:

90 g glucosa $\frac{1}{180}\frac{mol}{g}\frac{glucose}{glucose}\frac{6}{1}\frac{mol\ atoms\ O}{mol\ glucose}\frac{6.02x10^{23}\ atoms\ O}{mol\ atoms\ O}$ = $1.8x10^{24}$ atoms O

(a) [0.50]

ANSWER: $1.8x10^{24}$ atoms O (b) [0.10]

total [0.60]

3.5.1. During her straight line path, her velocity follows the graph as shown in the figure below. Find the instantaneous acceleration at points A, B and C.

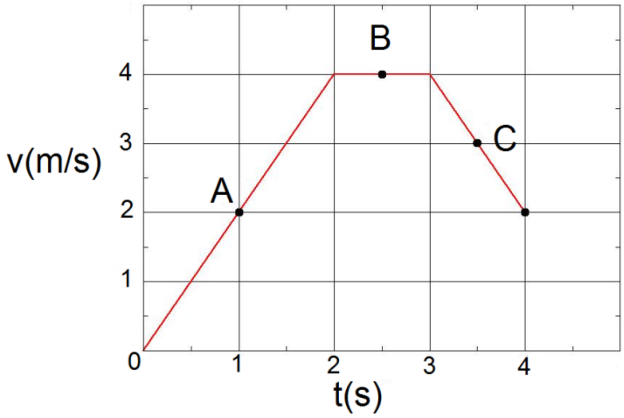


Figure 12: Velocity as a function of time

RESOLUTION

$$a_A = \frac{v_2 - v_0}{t_2 - t_0} = \frac{4\mathrm{m}\cdot s^{-1} - 0}{2\,s - 0} = 2\mathrm{m}\cdot s^{-2}$$

$$a_B = 0$$

$$a_C = \frac{v_4 - v_3}{t_4 - t_3} = \frac{2\mathrm{m}\cdot s^{-1} - 4\mathrm{m}\cdot s^{-1}}{4\,s - 3\,s} = -2\mathrm{m}\cdot s^{-2}$$

(a) [0.2]
(b) [0.2]
(c) [0.2]

ANSWER:
a_A = $2ms^{-2}$
a_B = 0
a_C =– $2ms^{-2}$

(d)[0.10]

total [0.70]

3.5.2. Calculate the distance she runs in the first two seconds the race.

RESOLUTION:

$$x_{de\,0\,a\,2s} = x_0 + v_0 \cdot (2s - 0s) + \frac{1}{2} \cdot a_A\,(2s - 0s)^2$$

$$x_{de\,0\,a\,2s} = 0 + 0 \cdot (2s - 0s) + \frac{1}{2} \cdot 2m \cdot s^{-2}\,(2s - 0s)^2$$

$$x_{de\,0\,a\,2s} = 4m$$

(a) [0.20]

(b) [0.20]

ANSWER: distance = 4 m

(c) [0.10]

total [0.50]

3.5.3. Calculate the minimum radius of her circular path. Consider a constant speed along the whole path.

RESOLUTION:

(a)[0.30]

ANSWER: **1.33 m**

(b)[0.10]

total [0.40]

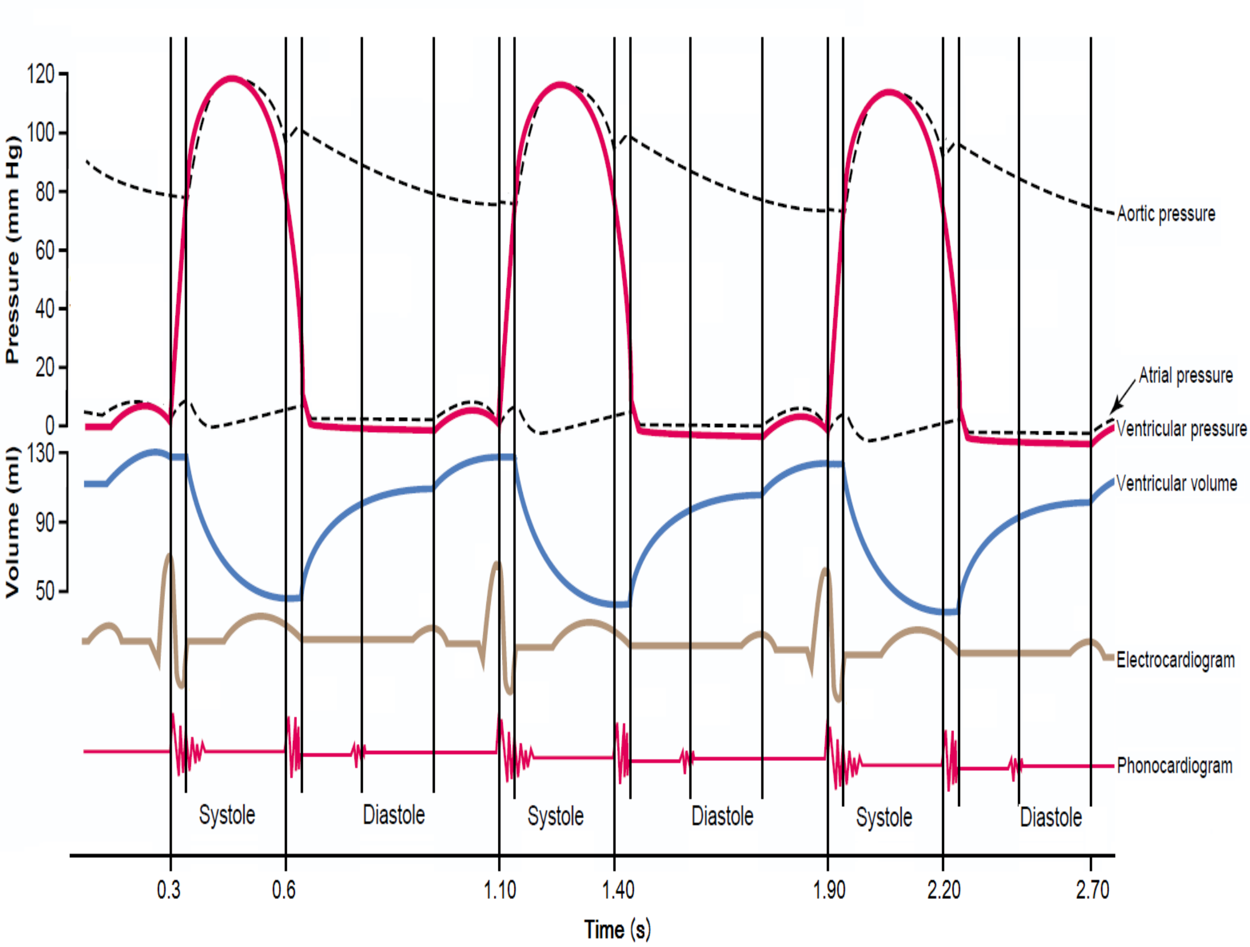


Figure 13: Various events occurring during three cardiac cycles, for different parts of the heart

3.6.1. Using the information shown in the graph, compute the time period of one cardiac cycle (in seconds).

RESOLUTION: One way to calculate it is: T = 1.10 s – 0.3 s = 0.8 s Another way: T = 1/f = 0.8s (a) [0.30]	
ANSWER: **0.8 s** (b) [0.10]	

total [0.40]

3.6.2. Calculate the corresponding heart rate (cardiac cycles per minute).

RESOLUTION:

According to the graph, the heart frequency is: 1 cycle/(1.10 s-0.3 s) = 1.25 s^{-1}
In beats per minute: (1.25 x 60) = 75 beats per minute

(a) **[0.40]**

ANSWER:

75 beats per minute

(b) [0.10]

total [0.50]

3.6.3. Indicate in which time intervals ventricular volume decreases considering that intervals in which the volume remains constant last 0.05 seconds.

ANSWER:
(0.35; 0.6) , (a) [0.1]
(1.15; 1.40), (b) [0.1]
(1.95; 2.20) (c) [0,1]

total [0.30]

3.6. 4. Indicate the maximum value observed for ventricular pressure.

ANSWER: 120 mm Hg

total [0.20]

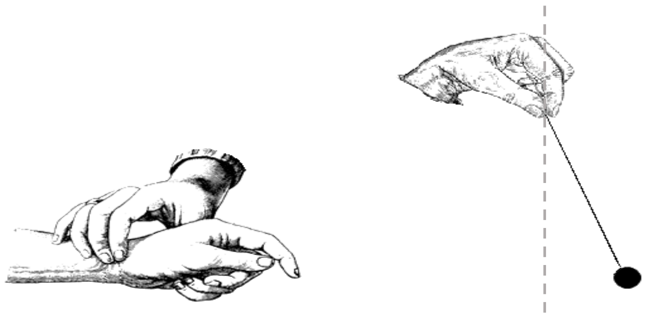


Figure 14: Pulse measurement using a simple pendulum.

3.7.1. Calculate the length of the pendulum used by the student, the period of simple pendulum is given by

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Being:
L the length of the pendulum
g= 9.81 m s^{-2}

RESOLUTION: By rule of three the period T of the pendulum is (0.4s) × (20)=T × (15) -> T = (0.4s) × (20/15)=0.53s (a) [0.2] From the expression for the period T=2π√(L/g) the longitude is cleared: L = g × (T/2π)^2= (9.81m/s^2) × (0.53s/2π)^2=**0.07m** (b) [0.2]
ANSWER: **0.07 m** **(c) [0.10]**

total [0.50]