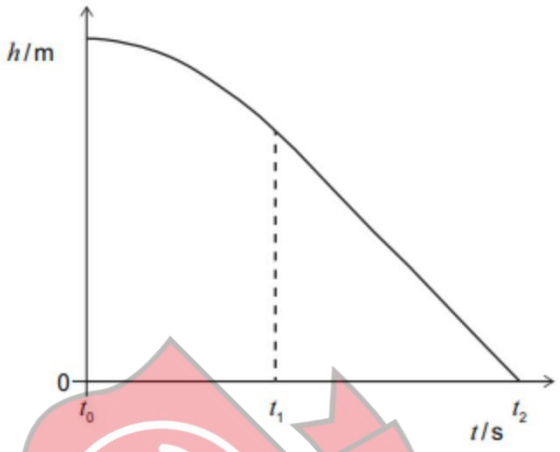
NSAA Section 2 2018 - Question P1

Question P1

A ball of mass m is dropped and falls vertically from a high window. The graph illustrates the height of the ball above the ground, h, as a function of time t since the ball was dropped.



a) In words, relate the speed of the ball to the gradient of the graph at time t_0, and in the two time intervals t_0 to t_1, t_1 to t_2.

[6 marks]

NSAA 2018 Section 2 - Question P1 (a) - Worked Solution

Statements to be included are:
- The speed of the ball is zero at the start (at t0)
- Therefore, the gradient of the line is zero (line is flat)
- Between t0 and t1: the ball is accelerating
- Therefore, the gradient of the line is always changing/the gradient is not constant
- (the gradient of the line tells us about the velocity of the ball)
- Between t1 and t2: the ball reached its terminal velocity
- Therefore, the gradient is constant; there is no resultant force on the ball

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b) The drag force on the ball caused by air resistance is given by F_d.

Using Newton's second law, find an equation for the acceleration a of the ball in terms of F_d, m, and g, where g is the gravitational field strength.

[2 marks]

NSAA 2018 Section 2 - Question P1 (b) - Worked Solution

Using Newton's second law (as told to in the question):
ag – Fd = ma
a = g – Fd/m

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c) The drag force on the ball is given by $F_d = \frac{1}{4}\pi\rho r^2 v^2$, where ρ is the density of the air, r is the radius of the ball, and v is the instantaneous speed of the ball.

Find an expression for the terminal speed of the ball v_t in terms of m, g, r and ρ.

[3 marks]

NSAA 2018 Section 2 - Question P1 (c) - Worked Solution

Terminal velocity implies that the acceleration is zero (a = 0) so the above expression simplifies to
Fd = mg
So (pi/4)r^2 rho (vt)^2 = mg
Rearrange for vt as the subject = (2/r)sqrt(mg/pirho)

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d) Calculate the value of the terminal speed of the ball given that it has a mass $m = 25\,\text{g}$, a radius $r = 25\,\text{cm}$, and that the density of the air $\rho = 1.2\,\text{kg}\,\text{m}^{-3}$.

(gravitational field strength = $9.8\,\text{N}\,\text{kg}^{-1}$)

[2 marks]

NSAA 2018 Section 2 - Question P1 (d) - Worked Solution

Substitute values into equation for vt above.
Convert 25g and 25cm into kg and m respectively.
Answer = 2.04m/s

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e) Sketch a graph of the ball's speed against time, labelling the terminal speed of the ball.

In words, relate the acceleration of the ball to the gradient of your speed–time graph.

[4 marks]

NSAA 2018 Section 2 - Question P1 (e) - Worked Solution

Speed against time graph drawn which is initially increasing at constant gradient (gradient = g at t0) then curves to level off at the terminal velocity. The statements to be made about relating the acceleration of the ball to the gradient include:

- The horizontal line (gradient = 0) means acceleration is zero
- Label vt on the graph
- The initial acceleration (at t0) is g

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f) The speed of the ball varies with height according to the equation

$$\left(\frac{v}{v_t}\right)^2 = \left(1 - 10^{-\frac{cy}{m}}\right)$$

where $m = 25\,\text{g}$, $c = 0.051\ \text{kg m}^{-1}$ and y is the distance the ball has fallen from the window; $y = 0$ at the start of the fall.

Calculate the distance that the ball has fallen when its speed is equal to 99% of its terminal speed.

[3 marks]

NSAA 2018 Section 2 - Question P1 (f) - Worked Solution

Firstly, recognize that if the speed is 99% of its terminal speed, the (v/vt) can be substituted for 0.99:
(0.99)^2 = (1 – 10^(-cy/m))
Take logs of both sides:
Log(0.99^2) = log(1 – 10^(-cy/m)) = log(1)/log(10^(-cy/m)) = log(1)/(-cy/m)
Rearranging and using log rules gives:
-cy/m = log (1 – 0.99^2)
Sub for c and m to get y = 0.83m or 83cm

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NSAA Section 2 2018 - Question P2

Question P2

Assume throughout this question that the cells and batteries have no internal resistance.

A light-emitting diode (LED) has the ideal I–V characteristic graph shown in Fig. 2a:

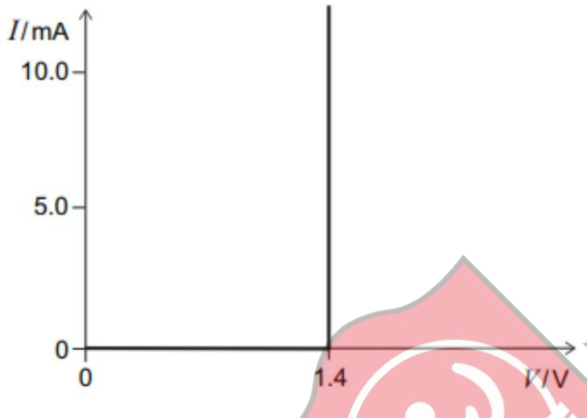

Figure 2a

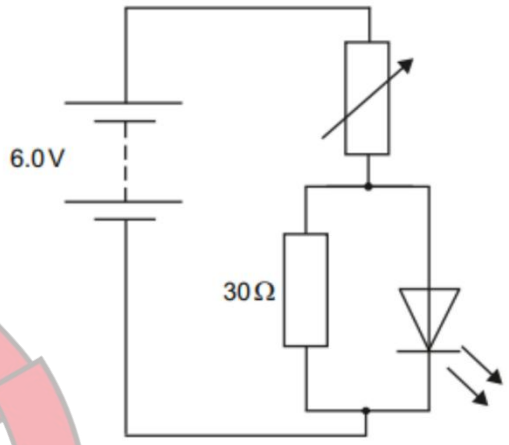

Figure 2b

If the potential difference across the LED is less than 1.4 V, no current passes through it. When a current does pass through the LED, the potential difference across it is always 1.4 V.

This LED is connected into the circuit shown in Fig. 2b, and the variable resistor is adjusted until there is a current of 8.0 mA through the LED. The battery has an emf of 6.0 V.

a) (i) What is the potential difference across the 30 Ω resistor? **[1 mark]**

(ii) What is the current through the 30 Ω resistor? **[1 mark]**

NSAA 2018 Section 2 - Question P2 (a) - Worked Solution

(a) (i)
The question states that the potential difference across the LED is always 1.4V and the 30 Ohm resistor is in parallel with it, therefore has the same pd across it = 1.4V

(a) (ii)
I = V/R = 1.4/30 = 0.047A

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b) (i) What is the current through the variable resistor? **[1 mark]**

(ii) What is the potential difference across the variable resistor? **[1 mark]**

(iii) What is the resistance of the variable resistor? **[1 mark]**

NSAA 2018 Section 2 - Question P2 (b) - Worked Solution

(i)
Variable resistor current: add currents through 30 Ohm resistor and LED (since current splits through parallel compenents):
Question tells us that current through LED is 8mA and from part (aii) current across the resistor is 47mA so 8 + 47 = 55mA

(ii)
Voltage splits across components in series, so if the pd across the parallel section is 1.4V, pd across the variable resistor = 6.0 – 1.4 = 4.6V

(iii)
R = V/I = 4.6/(55x10^-3) = 84 Ohms

(b)

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c) The following circuit is constructed with a battery of emf 6.0 V, two fixed resistors, one variable resistor, and a voltmeter, as shown in Fig. 2c.

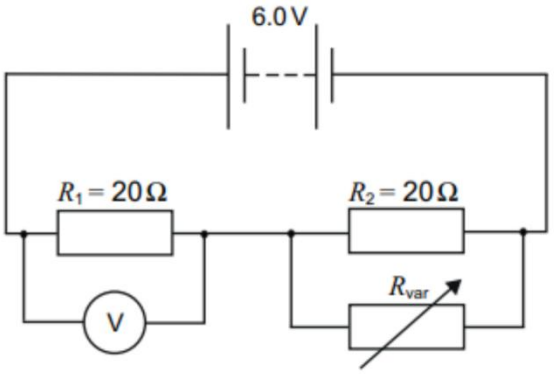

Figure 2c

$R_1 = R_2 = 20\,\Omega$, and R_{var} can be varied between 0 and 80 Ω.

(i) When R_{var} is set to 20 Ω, what is the voltage shown on the voltmeter?

[1 mark]

(ii) Sketch a graph of the voltage shown on the voltmeter against R_{var} for values of R_{var} between 0 and 80 Ω. Plot your result from part **(i)** on your graph.

[3 marks]

(iii) Calculate the potential difference across the variable resistor, and the power dissipated in the variable resistor, for R_{var} = 0.0 Ω, 5.0 Ω, 20 Ω, 50 Ω and 80 Ω.

[5 marks]

(iv) Using your results from part **(iii)**, sketch a labelled graph of the power dissipated in the variable resistor against R_{var} from 0 to 80 Ω.

[3 marks]

NSAA 2018 Section 2 - Question P2 (c) - Worked Solution

(i)

Requires use of the potential divider, where the total resistance of R2 and Rvar is given by: 1/RT = 1/20 + 1/20 = 1/10 so RT = 10 Ohms

V = 20/(20 + 10) x 6.0 = 4.0V

(ii)

Graph sketched: shows a downward curve starting at 6.0V for Rvar = 0 and levelling off at a 3.0V asymptote. Should aim to pass through the point V = 4.0V when R = 20 Ohms.

(iii)

Using the potential difference formula, V = Vi(Rvar/(20 + 2Rvar)) and P = V^2/Rvar:

For Rvar = 0, P = 0

Rvar = 5 P = 0.2W

Rvar = 20 P = 0.2W

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Rvar = 50 P = 0.125W
Rvar = 80 P = 0.09W

(iv)
There should be on the graph:
- Steep incline
- Max between 5 and 20 Ohms
- Shallow decline to P = 0.09 for 80 Ohms (not an asymptote here)
- Graph should go through points calculated above

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d) A potentiometer is a three-terminal device often used as a variable resistor by using only two of the three terminals (one end of the resistive track and the sliding contact). An example is shown schematically in Fig. 2d. In a logarithmic potentiometer the resistance varies with the angle of rotation, θ.

The graph in Fig. 2e shows how the logarithm of the resistance R_{AB} varies linearly with angle θ.

θ can vary between 0° and 270°.

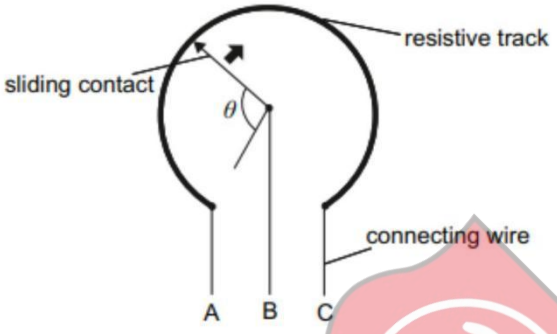

Figure 2d

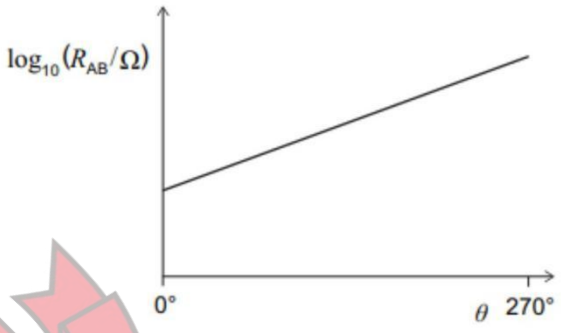

Figure 2e

If the resistance when $\theta = 0°$ is $R_{AB} = 1.00\,k\Omega$, and when $\theta = 270°$ is $R_{AB} = 2.00\,M\Omega$, what is the value of R_{AB} when $\theta = 110°$?

[3 marks]

NSAA 2018 Section 2 - Question P2 (d) - Worked Solution

log(Rab) = ktheta + c
log(Rab) = (log(2x10^6) – log(1x10^3))/270)theta + log(1x10^3)
= (log(2 + 6 – 3)/270)theta + 3
Sub for theta = 110 gives logRab = 4.345 so Rab = 22.1kOhms

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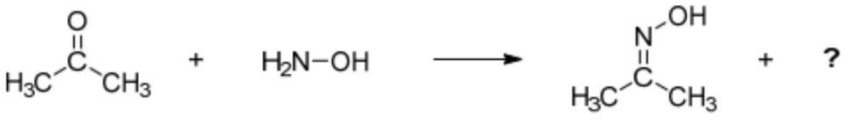
NSAA Section 2 2018 - Question C1

Question C1

a) Ketones react with hydroxylamine, NH_2OH, to give oximes. An example of such a reaction involving the ketone propanone is shown below:

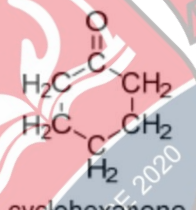


propanone (a ketone) | hydroxylamine | an oxime

(i) In addition to the oxime, this reaction produces a second product. Suggest what this molecule might be.

[1 mark]

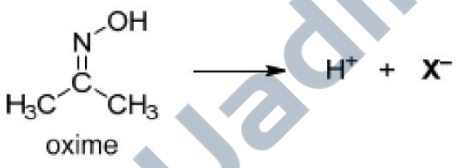
(ii) Draw the structure of the oxime that you would expect to be formed from the reaction of the ketone cyclohexanone with hydroxylamine.



cyclohexanone

[2 marks]

(iii) Oximes are weakly acidic. For the oxime below, explain which hydrogen atom will be the most acidic and draw the structure of the resulting anion X^-.



oxime

[3 marks]

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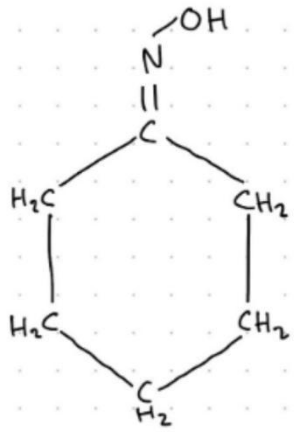
NSAA 2018 Section 2 - Question C1 (a) - Worked Solution

(i)
H20 or water

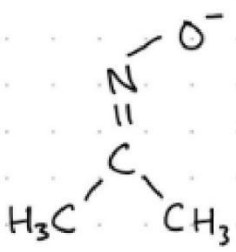
(ii)



Oxime = [1]

cycle = [1]

(iii)



correct structure [1]

O is electronegative [1]

Stabalises negative charge [1]

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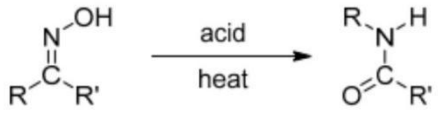
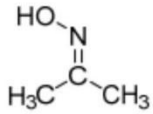
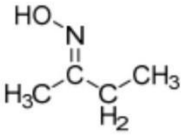
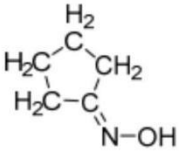
b) Under acidic conditions, oximes undergo the following rearrangement reaction (note carefully that there are two different groups R and R').



Give the analogous structures into which each of the following oximes rearrange under the same conditions.

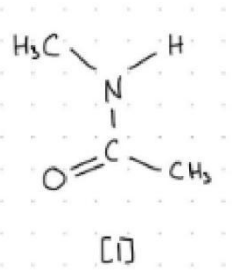


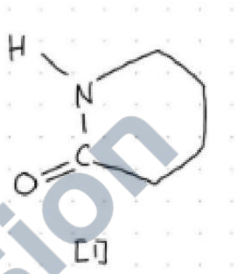




[4 marks]

NSAA 2018 Section 2 - Question C1 (b) - Worked Solution





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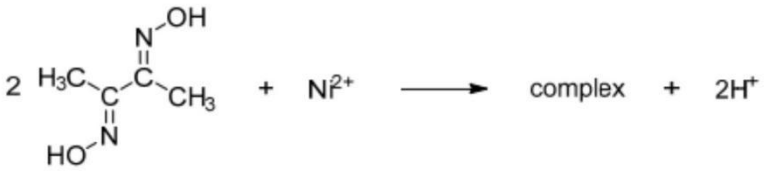
c) Dimethylglyoxime reacts with Ni^{2+} ions in aqueous solution under mildly basic conditions to give a complex which is an insoluble red precipitate. The reaction involves two molecules of dimethylglyoxime and also results in the production of two H^+ ions.



dimethylglyoxime

Assuming that the above equation is balanced, determine the **molecular formula** of the complex and its relative molecular mass; a structural formula is **not** required.

(Relative atomic mass data is given in the Periodic Table on page 14.)

[4 marks]

NSAA 2018 Section 2 - Question C1 (c) - Worked Solution

From the equation given: Ni (C4 O2 N2 H7)2 = NiC8O4N4H14
Relative molecular mass = 59.693 + (8 x 12.011) + (4 x 15.999) + (4 x 14.007) + (14 x 1.008)
= 59.693 + 96.008 + 63.996 + 56.028 + 14.112
288.922

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d) The reaction between dimethylglyoxime and Ni^{2+} ions can be used to determine the nickel content of alloys by weighing the amount of the red precipitate produced from a known mass of a sample of an alloy.

A sample of mass 1.50 g of an alloy was dissolved in dilute acid and an excess of dimethylglyoxime was then added to the resulting solution. The pH was then adjusted to make the solution mildly alkaline, and this resulted in the formation of a red precipitate. The precipitate was carefully filtered off, dried and then weighed. The mass of the dry precipitate was 0.368 g.

Determine the nickel content of the alloy, expressed as a percentage by mass.

[4 marks]

NSAA 2018 Section 2 - Question C1 (d) - Worked Solution

Mass of the dry precipitate/ Relative molecular mass = 0.368/288.922
= 1.2737 x 10^-3 mol
= the amount of Ni in mol

Mass of Ni = Mr x Mol
= 1.2737 x 10^-3 x 58.6934
= 0.07475 g

% mass of Ni = 0.07475/1.5 x 100
= 4.98 % (3 s.f.)

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e) Other metal ions, such as Pd^{2+} or Pt^{2+}, also react with dimethylglyoxime to give insoluble precipitates. What effect would the presence of palladium in the alloy have on the value of the nickel content determined using the method in part **d)**?

[2 marks]

NSAA 2018 Section 2 - Question C1 (e) - Worked Solution

These metal ions will precipitate leading to an increase in the mass of the dry precipitate
This would make the % mass of Ni calculated higher than its true value

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NSAA Section 2 2018 - Question C2

Question C2

a) Write a balanced chemical equation for the reaction between $CO_2(g)$ and $OH^-(aq)$, giving $CO_3^{2-}(aq)$ as one of the products.

[1 mark]

NSAA 2018 Section 2 - Question C2 (a) - Worked Solution

CO2 + 2OH^- --> CO3^2- + H2O

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b) An organic molecule is known to contain C, H and O only. A sample of mass 0.100 g is carefully burnt in the presence of excess oxygen. The resulting gases are passed over a desiccant (drying agent), and it is observed that the mass of the desiccant increases by 0.0931 g.

After passing through the desiccant the gases are bubbled through 25.0 cm^3 of a solution of 1.00 mol dm^{-3} NaOH. The solution is then titrated against 1.00 mol dm^{-3} HCl, and the end point is found to be when 14.7 cm^3 of the acid has been added.

(i) Calculate the amount in moles of H_2O produced by the combustion.

[2 marks]

(ii) Calculate the amount in moles of CO_2 absorbed by the NaOH solution.

[4 marks]

(iii) Hence determine the empirical formula of the organic molecule.

[6 marks]

NSAA 2018 Section 2 - Question C2 (b) - Worked Solution

(i)
Mass H20 = 0.0931g

Moles = 0.0931/ 16.00 +2 x 1.008
1.17 x 10^-3 mol

(ii)

14.7 cm^3 = 14.7 x 10^-3 dm^3

14.7 x 10^-3 dm^3 x 1.00 mol dm^-3 = 0.0147 mol of HCL

Number of moles of OH titrated is equal to the number of moles of HCL

The amount of OH that reacted with CO2 = (25 x10^-3 dm^3 x 1.00 mol dm^-3) - 14.7 x 10^-3 mol
= 10.3 x 10^-3 mol

2NaOH + CO2 --> Na2CO3 +H2O
2:1 ratio
Moles of CO2 = 10.3 x 10^-3 / 2
= 5.15 x 10^-3

(iii)
Moles of C = 5.15 x 10^-3 (answer from part ii)

Moles H = 2 x moles of H20
= 2 x 5.1676 x 10^-3 = 10.335 x 10^-3 mol

Mass of O in the sample
0.100g - (5.15 x 10^-3 mol x 12.00 g/mol) - (10.335 x 10^-3 mol x 1.008g/mol) = 0.02778g

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Moles O = 0.02778g/ 16.00 g/mol = 1.7364 x 10^-3 mol

Ratio- 3 : 6 : 1

Empirical formula = C3H6O

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c) Determine the oxidation state of the metal atom or atoms in the following species.

(i) MnO_4^{2-}

[1 mark]

(ii) $K_2Cr_2O_7$

[2 marks]

NSAA 2018 Section 2 - Question C2 (c) - Worked Solution

(i)
-2 - (-2) X 4 = +6

(ii)
K: + 1
Cr: (-2 - (-2) x 7) / 2 = +6

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d) Write a balanced chemical equation in which Fe^{2+} is oxidised to Fe^{3+} by MnO_4^- in an **acidic aqueous solution** and in which the Mn is reduced to a species with oxidation state +2. Your equation must balance for both atoms and charge, and you may **not** use free electrons (e^-) to achieve this.

[4 marks]

NSAA 2018 Section 2 - Question C2 (d) - Worked Solution

Fe 2+ --> Fe 3+ + e-

MnO4- + 5e- +8H+ --> Mn 2+ + 4H2O c
5Fe 2+ + 8H+ + MnO4- --> 5Fe3+ + Mn2+ + 4H20

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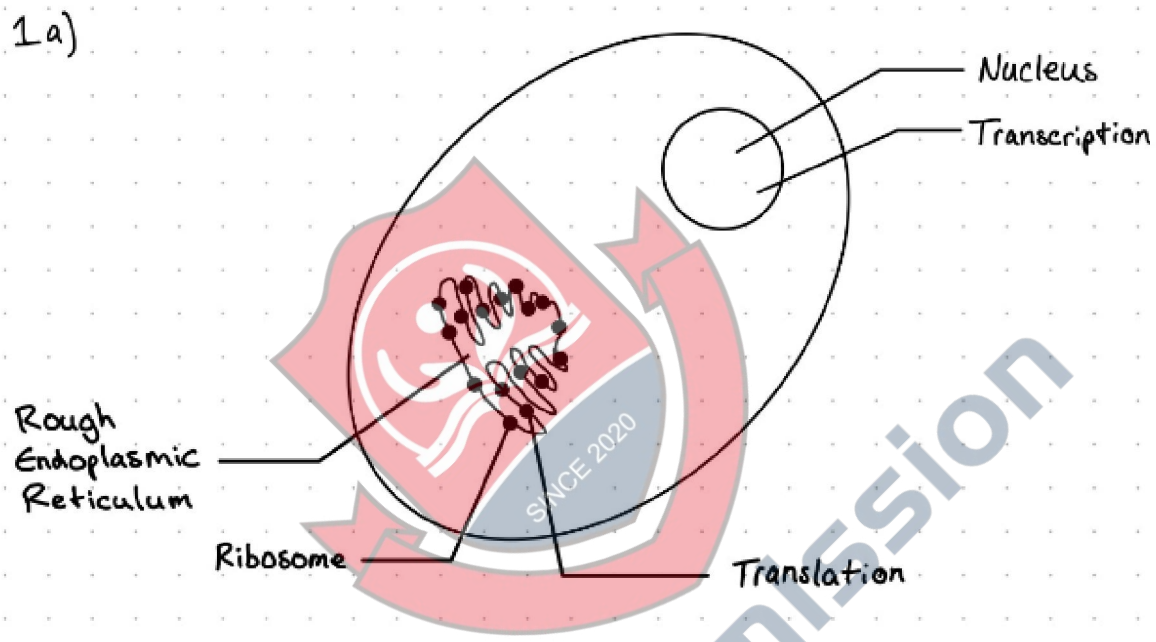
NSAA Section 2 2018 - Question B1

Question B1

a) Sketch a simple diagram of a eukaryotic cell, and label the locations where DNA transcription and RNA translation take place.

[2 marks]

NSAA 2018 Section 2 - Question B1 (a) - Worked Solution



Simple diagram, with transcription labelled in the nucleus [1]

And translation on free OR attached ribosomes in the cytoplasm [1]

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b) When RNA is translated into protein, it is read in triplets (codons).

What proportion of codons might be viewed as redundant in the genetic code (i.e. in excess of the minimum needed to code for all amino acids)?

[2 marks]

NSAA 2018 Section 2 - Question B1 (b) - Worked Solution

There are 4 possible nucleotides that are arranged into 3 letter sequences (codons), there are 64 possible combinations of these nucleotides (4^3).

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c) What is an advantage of having more codons in the genetic code than there are amino acids?

[2 marks]

NSAA 2018 Section 2 - Question B1 (c) - Worked Solution

The advantage of redundancy is that point mutations may lead to the same amino acid, which increases fault tolerance

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d) A ribosome can translate 18 bases per second.

How many seconds would it take to produce a protein that was 299 amino acids long?

[2 marks]

NSAA 2018 Section 2 - Question B1 (d) - Worked Solution

299 amino acids = 299 x 3 bases = 897. 897/18 = 49.833

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e) Imagine that an alien organism is found that translates its RNA using pairs of nucleotides instead of triplets.

During translation, the alien organism can use 50 possible amino acids (rather than the 20 found in humans).

What is the minimum number of different types of nucleotides that would be needed to code for all of the possible amino acids?

[2 marks]

NSAA 2018 Section 2 - Question B1 (e) - Worked Solution

7^2 = 49, too low, 8^2 = 64

4Uadmission SINCE 2020

f) Using examples, describe the changes that can occur in DNA sequences and explain how these changes can lead to diseases.

[10 marks]

NSAA 2018 Section 2 - Question B1 (f) - Worked Solution

Types of changes in DNA sequences

Substitutions: where one bases is swapped for anther. This changes the codon, which may lead to a change in the amino acid or a premature stop codon. These may alter the protein produced and therefore its function
Deletion: single or multiple bases can be lost from the sequence, leading to loss of amino acids or frameshift mutations. Frameshift mutations happen when there is a loss of a number of bases that is not a multiple of 3- altering the way the rest of the codons are read.
Insertion: single or multiple bases can be added to the sequence, this can lead to a gain of amino acids or frameshift mutations.

Examples:

Duchenne muscluar dystrophy is caused by deletion of exons in the DMD gene that alter the function of dystrophin
Cystic fibrosis is also caused by deletion in the CFTR gene, which alters either the production or functioning of the CFTR protein
Sickle cell anaemia is caused by a substitution mutation in the HBB gene, which encodes a protein in haemoglobin

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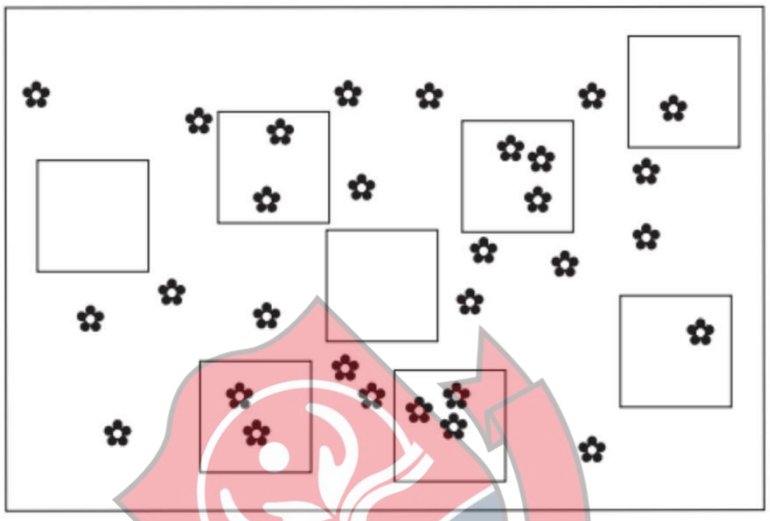
NSAA Section 2 2018 - Question B2

Question B2

The diagram below shows eight 2 m × 2 m quadrats that have been placed into a 14 m × 10 m field that has recently been colonised by a small invasive plant (each plant is shown by a flower symbol).

[diagram not to scale]



a) Describe one benefit **and** one problem associated with using quadrats in a study like this.

[2 marks]

NSAA 2018 Section 2 - Question B2 (a) - Worked Solution

benefit: increased speed or lower effort. Problem: Sample error, you are assuming that the quadrat samples are representative of the study area as a whole, if this is not true then the estimate will be inaccurate

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b) Calculate the frequency of occurrence of the species in the quadrats.

[1 mark]

NSAA 2018 Section 2 - Question B2 (b) - Worked Solution

Plant is found in 6 out of the 8 quadrats, therefore the frequency of occurance is 6/8

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c) Calculate the mean number of plants found per square metre in the quadrats.

[2 marks]

NSAA 2018 Section 2 - Question B2 (c) - Worked Solution

12 plants found within the quadrats, with a total area of 2 x 2 x8 = 32. Mean number of plants per square m = 12/32

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d) For the field as a whole, this population grows by 70 individuals per week.

How long will the population take to reach an average density of two plants per square metre in the 14 m × 10 m field?

[2 marks]

NSAA 2018 Section 2 - Question B2 (d) - Worked Solution

Final number of plants for an average density of 2 plants per square m = 14 x 10 x 2 = 280. 30 plants currently, need 250 more. 250/ 70 = 3.57 weeks or 25 days

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e) The invasive plant only produces flowers once every 5 years.

Explain why the plant produces flowers, and why flowers might be produced on this timescale.

[3 marks]

NSAA 2018 Section 2 - Question B2 (e) - Worked Solution

It may relate to one of the following:
importance of synchrony with its pollinators
Importance asexual reproduction
Importance of resource build up

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f) Discuss the factors that may affect the spread and photosynthetic rate of the invasive plant.

[10 marks]

NSAA 2018 Section 2 - Question B2 (f) - Worked Solution

Factors affecting photosynthetic rate: light intensity, CO2 levels, temperature, water, minerals. Increasing the light inensity or carbon dioxide concentration will increase the rate of photosynthesis until another factor becomes limiting, There is an optimal temperature for photosynthesis.
Factors affecting spread: limits on transmission (vactors for pollen, seeds), limits due to competition, limits due to the reproduction or growth rate (i.e, the slower a plant grows, the slower it can spread), limits due to environmental conditions.

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