# Bullet and Cannon (5 points)

Please read the general instructions in the separate envelope before you start this problem.

## Part A. The Modern day bullet (2.5 points)

Nitroglycerin is one of the important ingredients in modern day bullets. The self-combustion of this material is written as

$$2C_3H_5N_3O_9 \longrightarrow 6\,CO_2 + 3\,N_2 + 5\,H_2O + \tfrac{1}{2}\,O_2 + Heat$$

The amount of heat released is 666 kJ for 2 mole of nitroglycerine

11.35 g of this material is used in a cartridge of single bullet. The mass of the actual bullet is 100.0 g

| | | |
|---|---|---|
| **A.1** | Find the molar mass of nitroglycerine. | (0.5pt) |

| | | |
|---|---|---|
| **A.2** | Find the number of moles of nitro-glycerine in one bullet cartridge. | (0.5pt) |

| | | |
|---|---|---|
| **A.3** | Find the amount of energy released (numerical value in SI unit) during combustion of one bullet. | (0.5pt) |

| | | |
|---|---|---|
| **A.4** | Assuming that the entire energy evolved during combustion is used to give kinetic energy to the bullet.<br>Calculate the maximum possible muzzle speed (numerical value in SI unit) of this bullet. | (1.0pt) |

## Part B. Traditional Cannon (2.5 points)

A traditional Cannon barrel of inner diameter 15.0 cm and length 5.0 m was filled with gunpowder (nitrocellulose) to 20% of its length and topped with a cannon ball of same diameter as the barrel.

( Inner walls of the canon barrel are frictionless )

When it is fired, all of the nitrocellulose burns instantly and produces gas with pressure of 1000 standard atmosphere. When the ball exits the barrel the gas temperature drops to one third of the temperature ( in K) at the time of ignition.( Assume ideal gas situation)

( Neglect opposing atmospheric pressure )

| | | |
|---|---|---|
| **B.1** | Write the formula to find the pressure ( final pressure $P_2$ in terms of initial pressure $P_1$ , initial volume $V_1$ , initial temperature $T_1$ , final volume $V_2$ and final temperature $T_2$) when the cannon ball exits the barrel. | (0.5pt) |

| | | |
|---|---|---|
| **B.2** | Calculate the pressure (numerical value in SI unit) on the ball when it exits the barrel.<br>(Express your answers in three significant figures i.e. two digits after decimal) | (1.5pt) |

| | | |
|---|---|---|
| **B.3** | Calculate the force (numerical value in SI unit) on the ball when it exits the barrel.<br>(Express your answers in three significant figures i.e. two digits after decimal) | (0.5pt) |

# Bullet and Cannon (5 points)

**Instruction – column on the right side is for office use only - do not write in this space**

## Part A. The Modern day bullet (2.5 points)

**A.1** (0.5 pt)
The molar mass of nitroglycerine:

Answer:

**A.2** (0.5 pt)
Number of moles of nitroglycerine in one bullet cartridge:

Answer :

**A.3** $(0.5 \text{ pt})$
Amount of energy released (numerical value in SI unit) during combustion of one bullet:

Answer:

**A.4** $(1.0 \text{ pt})$
Maximum possible muzzle speed (numerical value in SI unit) of the bullet:

Answer :

## Part B. Traditional Cannon (2.5 points)

**B.1** (0.5 pt)
Formula to find the pressure when the cannon ball exits the barrel:

.

**B.2** (1.5 pt)
Pressure (numerical value in SI unit)) on the ball when it exits the barrel:

Answer:

**B.3** (0.5 pt)
Force (numerical value in SI unit)) on the ball when it exits the barrel:

Answer :

# The Sand buggy and Abra (5 points)

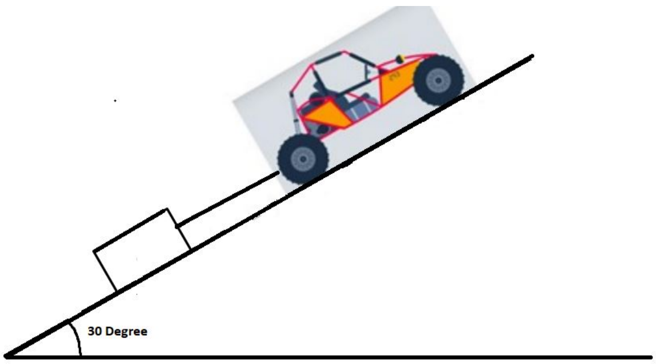
Please read the general instructions in the separate envelope before you start this problem.

## Part A. The sand buggy (3.0 points)

A sand buggy (shown in Figure 1) is a vehicle that is used for transportation in deserts. Consider a sand buggy travelling with a constant speed of 72.0 km/h climbing a sand dune which is shown as an inclined plane with an angle of inclination of $30^0$. The sand buggy is dragging a box of mass 200 kg upwards. The opposition to motion of the box offered by the sand is 0.15 of the normal force exerted on the box by the sand.

Figure 1 : Representative figure for sand buggy on a slope.

| | | |
|---|---|---|
| **A.1** | Draw a VECTOR diagram showing all forces acting on the box in the figure below. | (1.0pt) |




| | | |
|---|---|---|
| **A.2** | Calculate the total force (numerical value with proper unit) that opposes the motion of the box up the incline. | (0.5pt) |

| | | |
|---|---|---|
| **A.3** | Calculate the minimum power (numerical value in SI unit) exerted by the sand buggy on the box to sustain the upward motion. | (0.5pt) |

| | | |
|---|---|---|
| **A.4** | If the box is suddenly detached in the course of upward motion, calculate the retardation acting on the box.( Numerical value in SI unit) | (0.5pt) |

| | | |
|---|---|---|
| **A.5** | How far will will the box travel (numerical value in SI unit) before coming to rest after it detached from the sand buggy? | (0.5pt) |

## Part B. Abra boat ride (2.0 points)

Dubai city's traditional mode of transport to cross the creek is Abra boat ride (see Figure 2). Abra ride is one of the most economical modes of transport which connects the Old Dubai to New Dubai.

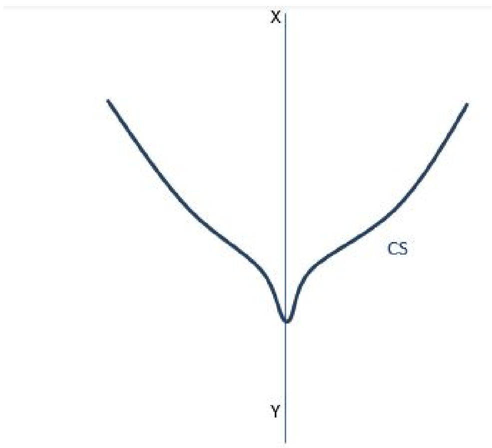
Figure 2 : Representative figure for Abra boat floating in water.

The boats are about 6 m in length and seating arrangement is made of two parallel lines of benches on either side of the vertical plane dividing the boat lengthwise. The center of mass of the boat lies on the vertical line passing exactly through the center of the benches. Passengers can seat on either side on the benches facing the creek.

When the passengers are seated, their centers of mass as a group can be considered to be at a height of 0.4 m above the deck. In case of a maximum payload the water level is 0.5 m below the deck, the buoyant force acts at a point 0.1 m below the water level and the center of mass of the boat lies 1.4 m below the deck. The mass of the unloaded boat is 1000 kg while the average mass of each passenger is 65 kg.

Assume that the point of action buoyant force does not change considerably.

| | | |
|---|---|---|
| **B.1** | Draw a schematic sketch along the line XY, of the positions of center of mass of the boat, center of buoyancy of the boat, center of mass of the passengers, and the deck level with respect to the water line and label the distances (need not be on scale). CS – Represents the vertical cross section of the boat in the figure given below. | (0.5pt) |



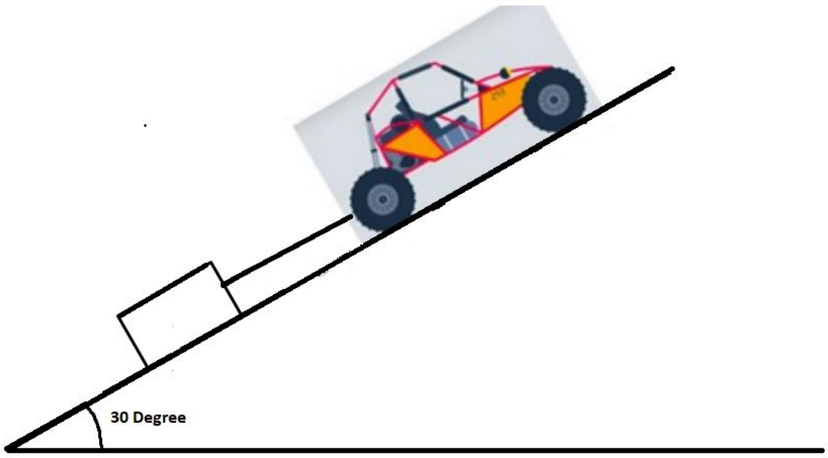

| | | |
|---|---|---|
| **B.2** | Calculate the maximum number of passengers can be seated such that the boat is prevented from capsizing. | (1.5pt) |

# The Sand buggy and Abra (5 points)

**Instruction – column on the right side is for office use only - do not write in this space**

## Part A. The sand buggy (3.0 points)

**A.1** (1.0 pt)
Draw a VECTOR diagram showing all forces acting on the box in the figure below.




**A.2** (0.5 pt)
Total force (numerical value in SI unit) that opposes the motion of the box up the incline.

Answer:

**A.3** (0.5 pt)
Minimum power(numerical value in SI unit) exerted by the sand buggy on the box to sustain the upward motion.

Answer:

**A.4** (0.5 pt)
During the course of its upward motion, its retardation (numerical value in SI unit).

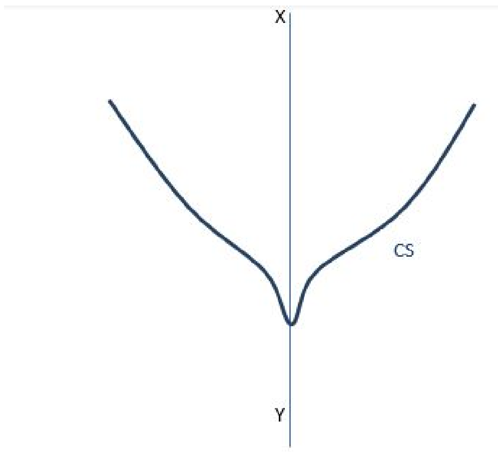
Answer:

**A.5** (0.5 pt)
Distance it travels (numerical value in SI unit) before coming to rest after it detached from the buggy.

Answer:

## Part B. Abra boat ride (2.0 points)

**B.1** $(0.5 \text{ pt})$
The schematic sketch along the line XY, of the positions of
(a) center of mass of the boat,
(b) center of buoyancy of the boat,
(c) center of mass of the passengers, and
(d) the deck level
with respect to the water line and label the distances.
CS – Represents the vertical cross section of the boat in the figure given below:




**B.2** $(1.5 \text{ pt})$
Calculate the maximum number of passengers that can be seated such that the boat is prevented from capsizing.

Answer:

**Please read the general instructions before you start this problem and also write the correct units for all the quantities wherever necessary.**

Dates are tropical fruits that grow on date palms. The origin of dates goes back to 5320 BC. Dates are a source of rich nutrients like carbohydrates, proteins, fibre, minerals, enzymes, and vitamins and thus form an essential staple food item for the people of UAE and other Middle East and North African countries. Dates are widely used in Emirati dishes. Dates have a high natural sugar content.

Sucrose (Molecular formula $C_{12}H_{22}O_{11}$ ),a disaccharide undergoes hydrolysis in excess of water by first order kinetics in the presence of an acid catalyst and obeys the rate law to give a mixture of two isomeric monosaccharides, Glucose ($C_6H_{12}O_6$) and Fructose ($C_6H_{12}O_6$). Solutions of these optically active carbohydrates can rotate the plane of plane polarized light. Sucrose is dextrorotatory (clock wise rotation, +) whereas the mixture of Glucose and Fructose is laevorotatory (anticlockwise rotation, -). $ln\ \frac{[C]_0}{[C]_t} = kt$

where, $C_0$ = initial concentration $C_t$ is concentration at time $t$ and $k$ is rate constant

The rate of hydrolysis of Sucrose is determined by measuring the angle of rotation of the plane of plane polarized light at regular time intervals during the course of the reaction. The angles of rotation are determined using a polarimeter.

A certain minimum amount of energy is required for the reaction in order to convert the reactants into products. This threshold energy for the reaction is called the Energy of Activation. It is determined by measuring the rate of a reaction at different t temperatures.

Use Arrhenius equation: $ln(k) = lnA - E/RT$

Where,

k = rate constant A= constant (independent of temperature) E= Activation energy R= Gas constant T= Absolute temperature

Note that $l_n x\ = (2.303\ \text{log}\ x)$

A student added 20 $cm^3$ of 1 M $HCl$ to 20$cm^3$ of 20 % Sucrose solution and transferred the mixture to a polarimeter tube of length 20 cm. He then recorded the angles of rotation at 303K and 311K as follows:

| Temperature (K) | Time (s) | Angle of rotation ($^\circ$) |
|---|---|---|
| 303 | 0 | +12.5 |
| 303 | 600 | -3.0 |
| 311 | 0 | +12.5 |
| 311 | 600 | -8.0 |

Use the rotation angle as a measure of concentration and consider that the relationship between the rotation angle and the concentration is linear

At the end of the hydrolysis, the angle of rotation was found to be -15.5$^0$.

| | | |
|---|---|---|
| **3.1** | Use the above information to :<br>1. Calculate the rate constants, k<br>2. Determine the energy of activation of the hydrolysis in kJ/mol | (2.0pt) |

UAE has huge reserves of oil and natural gas with most of the oil reserves located in Abu Dhabi. The Zakum oil field is the third largest oil field in the Middle East. UAE has one of the largest petroleum refining industries in the world. Naturally occurring petroleum is a complex mixture of hydrocarbons with different molecular weights. In the petroleum industry complex organic molecules of high molecular weight are broken down into lower molecular weight compounds which are in greater demand. A catalyst is used for this process which is called Catalytic Cracking. The rate of cracking of petroleum depends largely on the temperature of the catalyst used. Micro porous aluminosilicate minerals called Zeolites are commonly used to catalyse the cracking of petroleum, which occurs in the tiny pores of the mineral.

A catalyst increases the rate of a reaction by lowering its energy of activation. A zeolite catalyst lowered the energy of activation of the cracking of petroleum from 66 kJ /mol to 60 kJ /mol at 27$^{\circ}$C.

| | | |
|---|---|---|
| **3.2** | By what factor did the catalyst increase the reaction rate at 27$^{\circ}$C? | (1.0pt) |

A green mineral A is analysed and found to be composed of 9.72 % by mass of carbon, 38.85% by mass of oxygen, and the remainder a transition metal that forms $2^{+}$ ions. (A) is insoluble in water but dissolves with effervescence in dil $HCl$ giving a bluish green solution.When $H_2S$ gas is passed through this solution, a black precipitate (B) is obtained. (B) dissolves in dil $HNO_3$ giving a blue solution of C, yellow solid and a colourless gas. When aqueous $NaOH$ is added to this solution (C) a blue precipitate (D) is obtained that dissolves in ammonia solution to give a dark blue coloured solution.

| | | |
|---|---|---|
| **3.3** | Identify (A), (B), (C) and (D). Write correctly balanced chemical equations that (A), (B) , (C) and (D) involved in. (You do not have to write the equation of D with ammonia) | (2.0pt) |

**3.1** (2.0 pt)
**Solution**

**3.2** (1.0 pt)
**Solution**

**3.3** (2.0 pt)
**Solution**

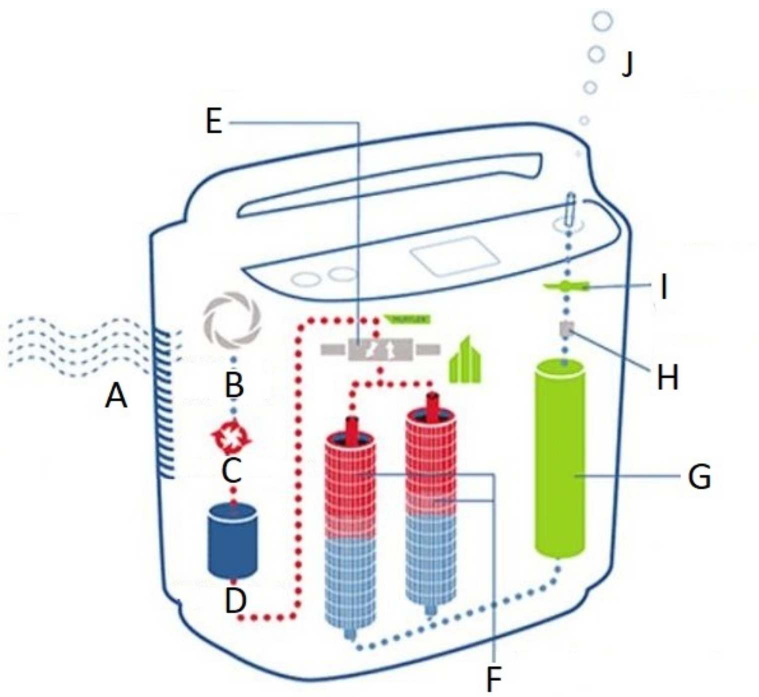
**Please read the general instructions before you start this problem and also write the correct units for all the quantities wherever necessary. (In solving this question consider the molar volume of a gas at STP is 22.4 L/mol). In all the following question, assume that STP conditions apply, unless otherwise stated.)**

The novel COVID-19 pandemic has brought unique challenges in various aspects of life. Coronaviruses belong to the family of viruses that causes severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS) and other related disorders.

Covid-19 is an airborne disease which transmits through by suspending infectious aerosols in air for considerable time.

United Arab Emirates (UAE) has taken unparalleled precautionary measures including deep sanitisation, mandatory vaccinations and other safety measure to curb it's spread..

Oxygen saturation in blood or $SpO_2$ is a measure of how much oxygen is carried by the blood as a percentage of its full capacity. Ideally oxygen level in the body should be 95 and above. However, in COVID-19, as the disease sometimes causes lung fibrosis and breathing problem, the oxygen level decreases. In such cases oxygen therapy is given. Oxygen concentrators are machines which are available with different capacities of oxygen. The machine separates the nitrogen and the oxygen by adsorption on zeolites. It takes oxygen from the atmosphere and supplies pure oxygen as its output.




**A**: air inlet; **B**: motor and compressor; **C**: heat exchanger; **D**: surge tank; **E**: four way solenoid; **F**: molecular sieve beds; **G**: product tank; **H**: pressure regulator; **I**; flow meter adjusting valve; **J**: pure oxygen outlet.

| | | |
|---|---|---|
| **4.1** | If air contains 21% of oxygen by volume, what volume air should the machine suck per day in order to get an oxygen supply of 1L/min for 15 min each, 4 times a day? | (0.5pt) |

The other types of oxygen generators dissociate acidified water by use of electricity and give out oxygen.

| | | |
|---|---|---|
| **4.2** | To get 1L/min for 15 min 4 times a day, what volume of water (in mL) should be poured into the machine per day? ( Assume complete electrolysis) | (0.5pt) |

A patient living at the seashore, requires a constant supply of pure oxygen through a nasal canula at the rate of 5 L/min. He has just got a new oxygen cylinder of capacity 340 L containing pure oxygen at pressure of 13700 k Pa. Assume that the temperature remains constant throughout and neglect the pressure of exhaled carbon dioxide.

| | | |
|---|---|---|
| **4.3** | After how many days will he need to replace his oxygen cylinder? | (0.5pt) |

The vaccine needs to be stored in dry ice. The dry ice, which is solid Carbon dioxide occupies 2840 L when it completely sublimes at 30$^\circ$ C and 1 atm.

| | | |
|---|---|---|
| **4.4** | If this dry ice is to be obtained from limestone having 80 % $CaCO_3$ content, what mass of limestone will be required? What is the total kinetic energy (in kJ) of these gaseous molecules? ( Ignore the contribution from the vibrational and rotational energy of the molecule) Assume that the gas behaves ideally $(K.E. = \frac{3}{2}nRT)$ | (1.5pt) |

| | | |
|---|---|---|
| **4.5** | What volume of oxygen (in L at 30$^\circ$C and 1 atm) would be needed for complete combustion of 1 mole of glucose ($C_6H_{12}O_6$)? What is the mass of oxygen required? | (1.0pt) |

The time taken for a certain volume of oxygen to effuse through a small hole is 1 hour.

| | | |
|---|---|---|
| **4.6** | Calculate the time taken, in seconds, by the same volume of carbon dioxide and chlorine to effuse through the same hole separately in the absence of oxygen.<br>$\sqrt{\frac{M_B}{M_A}} = \frac{Rate\, of\, effusion\, of\, gas\, A}{Rate\, of\, effusion\, of\, gas\, B}$<br>$M\, is\, the\, molar\, mass\, of\, the\, gas$ | (1.0pt) |

**4.1** (0.5 pt)

**4.2** (0.5 pt)

**4.3** (0.5 pt)

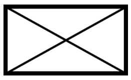
**4.4** (1.5 pt)

**4.5** (1 pt)

**4.6** (1 pt)

# General Instructions :

1. Only the answers marked or written in the answer sheet will be evaluated.
2. Indicate your answer by marking the column with a cross (**X**) as follows



Please read the general instructions in the separate envelope before you start this problem.

## Q.5. Date palm (6.75 points)

The date palm (*Phoenix dactylifera* L.) tree is a common sight in the Arabian Peninsula. Its fruits are eaten all over the world and are called dates.

Figure 5.1 represents a longitudinal section of the date fruit. Table 5.1 lists a set of tissues found in fruits.

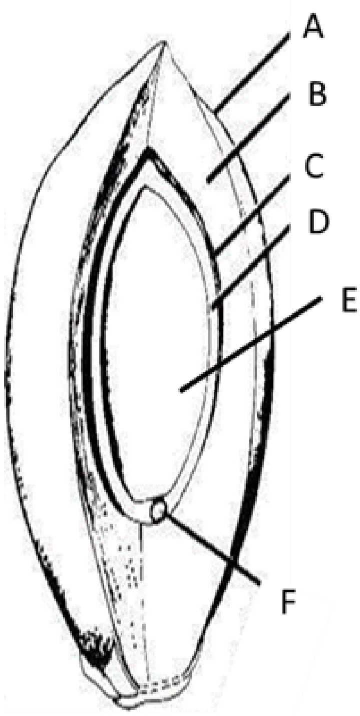



**Figure 5.1**. Longitudinal section of date fruit and seed.

| No. | Tissue |
|---|---|
| 1 | Testa |
| 2 | Endocarp |
| 3 | Epicarp |
| 4 | Mesocarp |
| 5 | Embryo |
| 6 | Endosperm |

**Table 5.1**

**5.1. Match the tissues mentioned in Table 5.1 with the letters in Figure 5.1.**

**A.5.1** **Mark a cross (X) in the appropriate column** corresponding to each of the labels (A to E). As an example, the correct answer for label F has already been given in the table below. (0.5pt)

| | Tissues | | | | | |
|---|---|---|---|---|---|---|
| Label | 1 | 2 | 3 | 4 | 5 | 6 |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |
| F | | | | | X | |

**5.2. From the tissues (1-6) mentioned in Table 5.1, which tissues are derived without the contribution of the male gamete?**

**A.5.2** **Mark a cross (X) in the appropriate column** (Yes/No) corresponding to each of the tissues. (0.25pt)

| **Tissue** | **Yes** | **No** |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

5.3. During ripening, the date fruits show changes in the starch and sugar content as shown in the plot below (Figure 5.2).

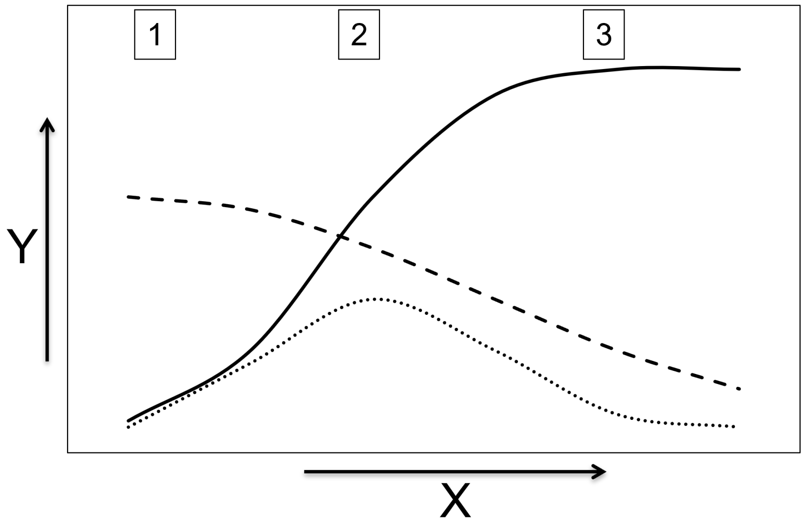



**Figure 5.2**

| | |
|---|---|
| X | Days of fruit ripening |
| Y | % content |
| ▬▬▬▬ | Total sugars |
| ▬ ▬ | Starch |
| . . . . | Sucrose |
| 1, 2, and 3 | Stages of fruit ripening |

Sucrose is synthesized in the leaves and transported to the fruit. In the fruit, sucrose is broken down into glucose and fructose by an enzyme A. Sugars are also formed by the breakdown of starch by enzyme B in the developing fruit. Total sugars include both mono- and di-saccharides.

The following statements were made:

Statement 1: The activity of enzyme B contributes to an increase in total sugars at stage 2.

Statement 2: The activity of enzyme A is higher at stage 1 than at stage 2.

Statement 3: The activity of both enzyme A and B is higher in the period between stage 2 and 3 than at stage 1.

**Based on the analysis of the plot (Figure 5.2), are the above statements ( 1 to 3) correct?**

**A.5.3** **Mark a cross (X) in the appropriate column** (Yes/No) corresponding to each of the statements. (1.0pt)

| Statement | Yes | No |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**5.4.** Invertase enzyme converts sucrose (disaccharide) to glucose and fructose (monosaccharides). One of the methods of estimating invertase activity is by measuring the level of glucose formed, using the glucose oxidase peroxidase method. In this method, the amount of glucose is estimated as the absorbance of the end product measured at 562 nm ($A_{562}$). A standard plot of $A_{562}$ for different glucose concentrations as measured by the glucose oxidase peroxidase method is presented in Figure 5.3.

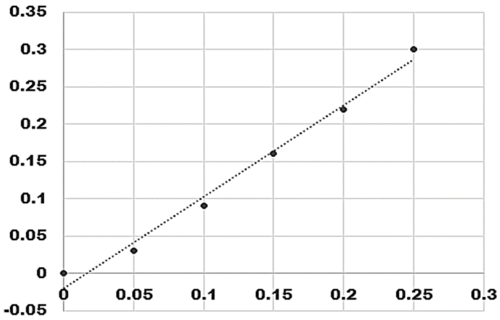



**Figure 5.3.** X-axis = Glucose concentration (mg/ml); Y-axis = $A_{562}$

Invertase activity is denoted in terms of enzyme units (U). One U invertase is defined as the amount of enzyme that will produce 1 μmol of glucose in 1 min at $30^0$C.

In an experiment, the following reaction was set up to measure invertase activity:

i. 0.6 ml of buffer

ii. 0.2 ml of 400 mM sucrose

iii. 0.2 ml of invertase enzyme stock

- The reaction mixture was incubated at $30^0$C for 30 min, after which the reaction was stopped, by increasing the temperature.
- Glucose formed at the end of the reaction was estimated by glucose oxidase peroxidase method, and $A_{562}$ was recorded.
- $A_{562}$ **was observed to be 0.1**.

Based on the above information, answer the following questions:

**Calculate the amount of sucrose in terms of μmoles that was present in the reaction mixture.**

| | |
|---|---|
| **A.5.4.1 Amount of sucrose =** | (0.5pt) |

**Based on the observed absorbance, what was the concentration of glucose (mg/ml) formed at the end of the reaction?**

| | |
|---|---|
| **A.5.4.2** **Concentration (mg/ml) of Glucose** = | (0.25pt) |

**Calculate the amount of glucose in μmoles that was formed at the end of the reaction (M.W. of glucose = 180). Write your answer to 3 decimal points.**

**In case you are unable to answer 5.4.2,** use 0.4 mg/ml as the concentration of glucose.

| | |
|---|---|
| **A.5.4.3** **Amount of Glucose =** | (0.75pt) |

**Calculate the invertase activity as U/ml of the invertase enzyme stock. Write your answer to 3 decimal points.**

**In case you are unable to answer 5.4.3,** use 0.973 $\mu$mole as the amount of glucose.

| | |
|---|---|
| **A.5.4.4** **Invertase activity =** | (1.5pt) |

**5.5**. A researcher purified invertase from 1 kg of de-seeded date fruits. These fruits were homogenized in a suitable buffer and filtered using 4 layers of muslin cloth to obtain a crude extract. The crude extract was subsequently fractionated through a series of protein purification steps to enrich the invertase enzyme. Purification steps were designed to remove contaminating proteins with minimum loss of enzyme activity.

These steps involved (i) protein precipitation with $(NH_4)_2SO_4$ , (ii) affinity column chromatography and (iii) anion exchange chromatography in a sequential manner. Invertase activity (U) and the protein content (mg) were measured at each step of purification. Also, (i) specific activity of enzyme and, (ii) % recovery were calculated at each step to assess the purification efficiency.

A step which removes the maximum amount of contaminating proteins with minimum loss in enzyme activity is considered as an efficient purification step.

- Specific activity of invertase is calculated as the enzyme activity per mg protein (U/mg).
- The % recovery can be represented as the percent of invertase activity (U) recovered after each step of purification in comparison to that of the crude extract.

Table 5.2 records the invertase activity and total protein in crude extract (step 1) and that recovered after different steps (2 to 4) of purification.

**Calculate the specific activity of invertase at steps 1 to 4 and the % recovery for steps 2 to 4. Record your answer (to 3 decimals) in Table 5.2:**

**A.5.5.1** (1.0pt)

| Table 5.2 | | | | | |
|---|---|---|---|---|---|
| **Step Number** | **Purification step** | **Invertase activity (U)** | **Total protein (mg)** | **Specific activity of invertase** | **% recovery of invertase** |
| 1 | Crude extract | 13,773 | 13,746 | | |
| 2 | Ammonium sulphate precipitation | 12,469 | 8,234 | | |
| 3 | Affinity chromatography | 11,487 | 836 | | |
| 4 | Anion exchange chromatography | 11,156 | 567 | | |

Based on the information given in Table 5.2, answer the following questions:

**A.5.5.2** Identify the step number (2 to 4) that led to the most efficient purification of invertase by **marking a cross (X) in the appropriate box**. (0.5pt)

| Steps | 2 | 3 | 4 |
|---|---|---|---|
| | | | |

It is observed that there is a loss of an enzyme activity during different steps of purification.

**A.5.5.3** Identify the step where there is maximum loss in the enzyme activity, by **marking a cross (X) in the appropriate box**. (0.5pt)

| Steps | 2 | 3 | 4 |
|---|---|---|---|
| | | | |

## Q.5. Date palm Answer Sheet(6.75 points)

**A.5.1** (0.5 pt)

| | Tissue | | | | | |
|---|---|---|---|---|---|---|
| Label | 1 | 2 | 3 | 4 | 5 | 6 |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**A.5.2** (0.25 pt)

| Tissue | Yes | No |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

**A.5.3** (1.0 pt)

| Statement | Yes | No |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**A.5.4.1** (0.5 pt)
**Amount of sucrose =**

**A.5.4.2** (0.25 pt)
**Concentration (mg/ml) of Glucose** =

**A.5.4.3** (0.75 pt)
**Amount of Glucose =**

**A.5.4.4** (1.5 pt)
**Invertase activity =**

**A.5.5.1** (1.0 pt)

**Table 5.2**

| Step Number | Purification Step | Inverse activity (U) | Total protein (mg) | Specific activity invertase | % recovery of invertase |
|---|---|---|---|---|---|
| 1 | Crude extract | 13,773 | 13,746 | | |
| 2 | Ammonium sulphate precipitation | 12,469 | 8,234 | | |

**A.5.5.1 (cont.)**

| Step Number | Purification step | Invertase activity (U) | Total protein (mg) | Specific activity invertase | % recovery of invertase |
|---|---|---|---|---|---|
| 3 | Affinity chromatography | 11,487 | 836 | | |
| 4 | Anion exchange chromatography | 11,156 | 567 | | |

**A.5.5.2** (0.5 pt)

| Steps | 2 | 3 | 4 |
|---|---|---|---|
| | | | |

**A.5.5.3** (0.5 pt)

| Steps | 2 | 3 | 4 |
|---|---|---|---|
| | | | |

## Q.6. Theory II – Bird populations ( 3.25 points)

A **population** is a group of individuals of the same species that live in the same area and interbreed, producing fertile offspring. The population's genetic makeup is characterized by describing its **gene pool**, which consists of all copies of every type of allele at every locus in all the members of the population. If only one allele exists for a particular gene in a population, that allele is said to be fixed in the gene pool. If there are two or more alleles for a particular gene in a population, individuals may be either homozygous or heterozygous.

The frequency of different alleles in a population is presented as the number of that allele present out of the total number of alleles for a given gene. For example, a population has 1000 copies of alleles for a given gene. If one of the alleles (X) of this gene has 100 copies the frequency of allele X is 0.1.

If a population is not evolving, the frequency of alleles will remain constant generation after generation. Such a population is said to be in equilibrium, as defined by Hardy and Weinberg; hence called Hardy-Weinberg equilibrium. The Hardy-Weinberg equilibrium can be described by the equation $p^2 + 2pq + q^2 = 1$, where p and q are frequencies of two alleles of a gene.

Scientists studied a population of 10,000 birds in a forest area. This **parental population** has birds with red, pink, or white beaks. Mating between birds with red and white beaks leads to a progeny with birds with pink beaks. If birds with pink beaks are randomly mated, the progeny has birds with red, white and pink beaks in a ratio of 1: 1: 2. Beak color is governed by two alleles, $B^R$ and $B^W$.

**Which of the following can describe the relationship between the alleles $B^R$ and $B^W$? Mark the column Yes with a cross (X), if the description of the allelic relationship is correct and in column No if it is incorrect.**

**A.6.1** (0.25pt)

| S.No. | Relationship | Yes | No |
|---|---|---|---|
| 1. | Co-dominance | | |
| 2. | Incomplete dominance | | |
| 3. | Over dominance | | |
| 4. | Dominant-recessive | | |

**6.2.** A DNA-based test was carried out to identify the genotypes of all the 10,000 birds in the above population. The observation is summarised in Table 6.1:

| Phenotype | Genotype | Number of birds |
|---|---|---|
| Red beak | $B^R B^R$ | 6400 |
| Pink beak | $B^R B^W$ | 3200 |
| White beak | $B^W B^W$ | 400 |

**Table 6.1**

**What is the frequency of the alleles $B^R$ and $B^W$ ?**

**A.6.2** **Frequency of $B^R$ =** (0.5pt)

**Frequency of $B^W$=**

**6.3.** All the birds in the parental population were tagged. After 6 months, the scientists visited the population and observed that 5,000 new chicks were born (Generation I). Observation following analysis of generation I is summarised in Table 6.2:

| Phenotype | Genpotype | Number of birds |
|---|---|---|
| Red beak | $B^R B^R$ | 3200 |
| Pink beak | $B^R B^W$ | 1600 |
| White beak | $B^W B^W$ | 200 |

**Table 6.2**

Based on comparing the observations in Table 6.1 and 6.2, the following statements were made:

Statement 1: The frequency of $B^R$ and $B^W$ alleles is the same in generation 1 and the parental population.

Statement 2: Random mating occurred in the parental population.

Statement 3: The population is not evolving.

**Are the above statements ( 1 to 3) correct?**

**A.6.3** Mark a cross (X) in the appropriate column (Yes/No) corresponding to each of the statements. (0.5pt)

| Statement | Yes | No |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**6.4.** 1000 chicks of generation I were transferred to an island before they matured to reproduce (were able to produce gametes). Of the 1000 chicks, 336 birds had red beaks, 504 birds had pink beaks and 160 birds had white beaks. Further, after the birds were moved to the island, it was observed that birds with white beaks were infertile. Random mating in this population led to 100 newborn chicks.

**Calculate the number of chicks expected to have either (i) red beaks or (ii) pink beaks.**

**A.6.4** **6.4.1. Red beak =** (1.5pt)

**6.4.2. Pink beak =**

**Which of the following conditions are essential for a population to be in Hardy-Weinberg equilibrium?**

**A.6.5** Mark a cross (X) in the column Yes, if it is essential or in column No is it is non-essential. (0.5pt)

| S.No. | Condition | Yes | No |
|---|---|---|---|
| 1. | Occurrence of mutations | | |
| 2. | No gene flow (Transfer of genetic material from one population to another) | | |
| 3. | Random mating | | |
| 4. | Natural selection | | |
| 5. | Small population size | | |

## Q.6. Bird populations Answer Sheet (3.25 points)

**A.6.1** $(0.25\ \text{pt})$

| S.No. | Relationship | Yes | No |
|---|---|---|---|
| 1. | Co-dominance | | |
| 2. | Incomplete dominance | | |
| 3. | Over dominance | | |
| 4. | Dominant-recessive | | |

**A.6.2** $(0.5\ \text{pt})$

**6.2.1.** Frequency of $B^R =$

**6.2.2.** Frequncy of $B^W =$

**A.6.3** (0.5 pt)

| Statement | Yes | No |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**A.6.4** (1.5 pt)

**6.4.1.** Red beak =

**6.4.2.** Pink beak =

**A.6.5** (0.5 pt)

| S.No. | Condition | Yes | No |
|---|---|---|---|
| 1. | Occurrence of mutations | | |
| 2. | No gene flow | | |
| 3. | Random mating | | |
| 4. | Natural selection | | |
| 5. | Small population size | | |