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 nitration (self-combustion) of this material is written as

$$2C_3H_5N_3O_9 \longrightarrow 6\,CO_2 + 3\,N_2 + 5\,H_2O + \tfrac{1}{2}\,O_2 + 666\,kJ$$

11.35 g of this material is used in a bullet cartridge of mass 100.0 g.

A.1	Find the molecular 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 with proper 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. Calculate the maximum possible muzzle velocity (numerical value with proper unit) of this bullet.	(1.0pt)

Answer:

Maximum kinetic Energy is possible only when the entire energy evolved during combustion is used to give kinetic energy to the bullet.

(a) Molecular mass of nitro-glycerine = 227 **(0.5 Mark)**

So 11.35g will correspond to 0.05 Mole **(0.5 Mark)**

Releasing 16650 J of energy **(0.5 Mark)**

$\frac{1}{2}mv^2 = 16650;$

$v = \sqrt{2 \times \frac{16650}{0.1}} = \mathbf{5.77 \times 10^2 m/s}$ **(1 Mark)**

(Deduct 0.5 if unit is not written along with numerical answer)

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(b) The gases expand through the barrel.

Apply formula $P_1V_1/T_1 = P_2V_2/T_2$ **(0.5 Mark)**

Let V be the volume of the barrel:

$V = l\frac{\pi D^2}{4}$ (not necessary to use)

P_1 = 1000 atm, $V_1 = 0.2 \times V$, $V_2 = V$, $T_2 = \frac{1}{3}T_1$ **(1.0 Mark)**

(Any one part wrong would lead to deduction of 0.25 Mark)

Calculate: $P_2 = \frac{P_1V_1}{V_2}.\frac{T_2}{T_1} = \frac{P_1}{15} = \frac{\mathbf{1000 \times 1 \times 10^5}}{\mathbf{15}} = 6.67 \times 10^6\ N/m^2.$ **(0.5 Mark)**

(No Unit – Deduct 0.25 Mark)

Force is P X A = $P_2 \times \frac{\pi D^2}{4} = \mathbf{6.67 \times 10^6} \times \frac{\boldsymbol{\pi \times 0.15 \times 0.15}}{\mathbf{4}}$ =1.178 x10^5 N

F= 1.18 X 10^5 N **(0.5 Marks)**

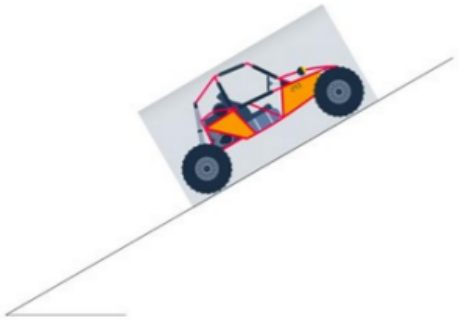
(Double penalty to be avoided) (No Unit – Deduct 0.25 marks)

Long Question 2a (3 Marks)

A sand buggy (shown in Figure 1) is a vehicle that is used for transportation in deserts. Consider a sand buggy of mass 200.0 kg travelling with a speed of 72.0 km/h climbing a sand dune which is shown as an inclined plane with an angle of inclination of 30^{o}. The opposition to this motion offered by the sand is a fraction f = 0.15 of the normal force exerted on the buggy 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 vehicle in the figure below. (1.0pt)



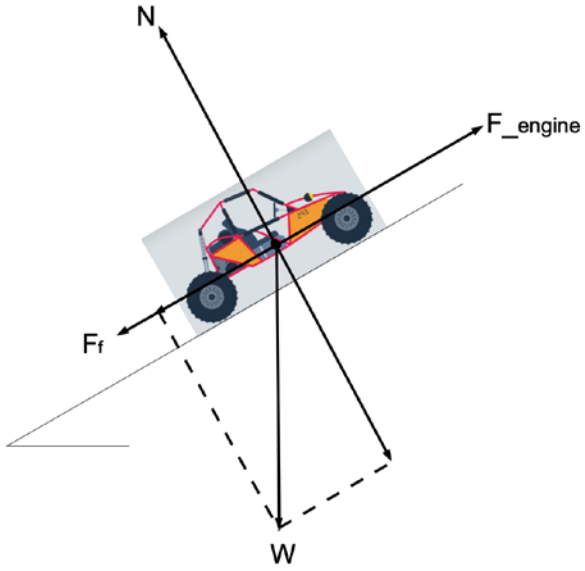
A.2 Calculate the total force (numerical value with proper unit) that opposes the motion of the sand buggy up the incline. (0.5pt)

A.3 Calculate the minimum power (numerical value with proper unit) of the engine of the sand buggy to sustain the upward motion. (0.5pt)

A.4 If the engine suddenly stops during the course of its upward motion, calculate its retardation (numerical value with proper unit) . (0.5pt)

A.5 How far will it travel (numerical value with proper unit) before coming to rest after the engine suddenly stops ? (0.5pt)

Answer: the diagram on the question paper is to be printed on the answer space in the answer sheet,



0.25 marks for each correct direction shown 4 × 0.25 **(1.0 Mark)**

Part (ii) to (iv) 0.25 Marks to be deducted if the units are missing/wrong

(ii) $F_f + mg\sin(30) = mg[0.15\cos(30) + \sin(30)] = 1235\,N$

F = 1.24 x 10³ N **(0.5 Mark)**

(iii) $P_{min} = F_{engine}\,v = [F_f + mg\sin(30)]\,v = 24692\,W$

P = 2.47 x 10⁴ W **(0.5 Mark)**

(iv) $a = \dfrac{F_f + mg\sin(30)}{m} = 6.17\,m/s^2$ **(0.5 Mark)**

$s = \dfrac{v^2}{2a}$ $\quad s = \dfrac{20^2}{2\times 6.17} = 32.4\,m$ **(0.5 Mark)**

(0.25 mark to be deducted for not writing correct unit)

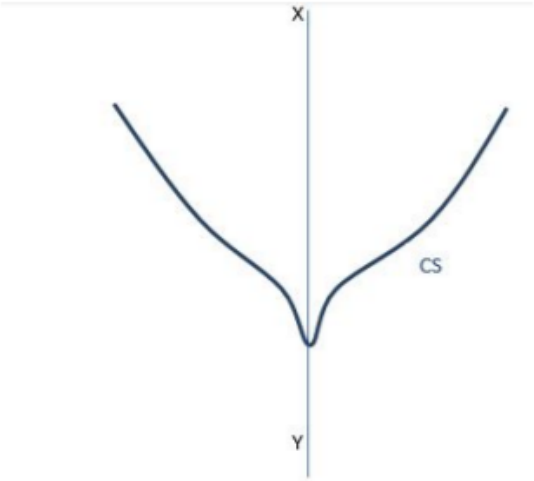
Long question 2b (2 Marks)

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

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 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 1.6 m below the deck. The mass of the unloaded boat is 1000 kg while the average mass of each passenger is 60 kg.

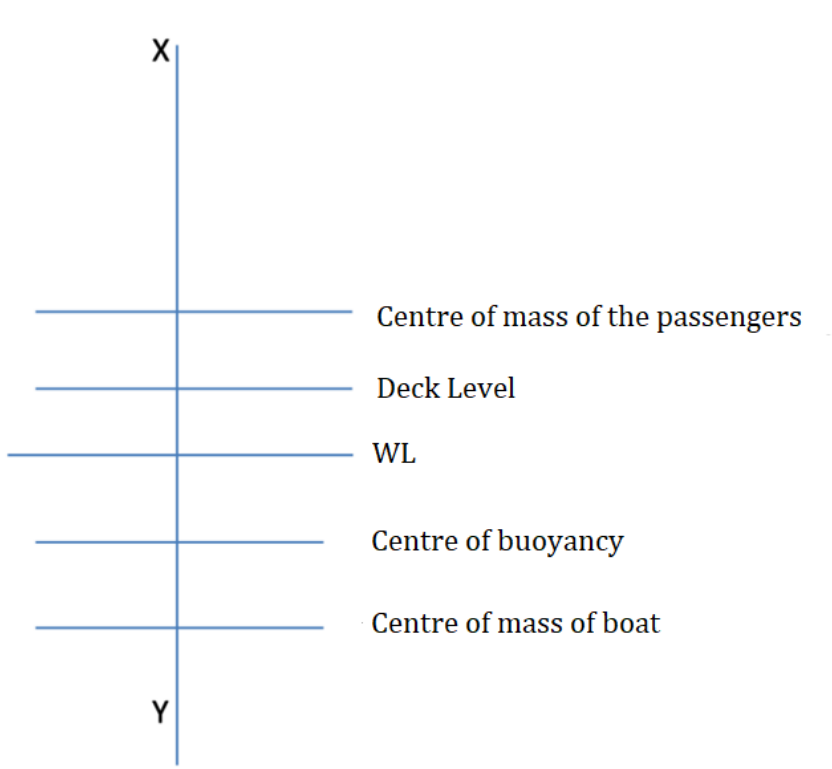
B.1 Draw a schematic sketch along the line XY, of the positions of center of mass of the boat, center of buoyancy of the boat, center of mass of the passengers, and the deck level with respect to the water line and label the distances. CS – Represents the vertical cross section of the boat in the figure given below. (0.5pt)



B.2 Calculate the maximum number of passengers such that the boat is prevented from capsizing. (1.5pt)

Answers:

1. **(0.5 Mark)**



(The picture of cross section is to be printed in the answer sheet and labeling is to be done in the answer key. The deck level should be included)
Every mistake deduct 0.1 Mark

2. Consider the number of passengers to be 'n'.

   With respect to the point where the buoyant force acts- is now:

   60n X 1.0 < 1000 X 1.0 (equality is also acceptable) **(1 Mark)**

   The answer is 16 **(0.5 Mark)**