Instructions:

Answer 3 out of the 6 questions.

No extra credit will be given for more than three answers. If more than three questions are attempted, CLEARLY indicate which questions are to be graded, otherwise only the first three answers will be graded, and the rest ignored.

Show all calculation steps to ensure that partial credit is earned, even if the final answer is incorrect. In cases where the answer is obviously wrong, some credit will be given if you identify this as an improbable answer.

If you make any assumptions, clearly state these assumptions. If you run out of time briefly describe how you would answer the remaining questions, to receive partial credit

Drag Forces

$D_f = [C_d * \rho_a * A * V * V] / 2$

$C_d = 24/N_{re}$ $(N_{re}=<1)$ $C_d = 26.38*N_{re}^{(-.845)} + .49$ $(N_{re}>1)$

$N_{re} = \rho_a * V * D_p / \mu_a$

$\mu_a = 4.79*10^{-6} \exp (0.678 + 0.00227*T)$ (Note T= Temperature in degrees Kelvin)

$\rho_a = P / [(8.314/29) * T]$

Sprayer Equations

$P\ (kw) = p*Q/60{,}000$

$s_m = 5.39*A^{0.422}*R^{-0.531}*Fe^{0.293}$

$P_s = 3.26*10^{-11}*R^{0.582}*s_m^{3.41}*L$

$Q_m = 3830\ V*F_e / p^{0.56}$

$Q_m = 1380\ V*F_e / p^{0.30}$

$Q = Cd*A*(2*\Delta p/\rho)^{0.5}$

$$D_{pq}^{p-q} = \left(\frac{\sum_{i=1}^{n} N_i D_i^p}{\sum_{i=1}^{n} N_i D_i^q} \right)^{1/(p-q)}$$

Forage Harvestors

$F_u = I/c * S_u/L$ $I = \pi d^4 /64$ $I = 3\pi d^3 t/32$

$\varsigma_r = F_r*L^3/(C_b*E*I)$ $C_b = 3$ or 48

$P_c = Esc*m_f/L_c$ $P_f = \beta\mu*m_f*V_{pc}*V_{pc}\ /1000$

$P_{accel} = m_f*V_{pc}*V_{pc}\ /2000$ $P_{aur} = m_f*V_{pc}*V_{pc}*V_{pc}\ /16600$

$P_h = C_{ho}+C_{h1}*m_f$

Combines

$GL = e-bL$

$b = 648.4*m^{-1.296}*(MOG/Grain)^{-0.662}$

Units:

1 hectare = 10,000 m^2

1 acre = 43,560 ft^2

1 Litre = 1000 mL = 1000 cm^3

1 gal = 231 in^3

Question 1: The boom on a sprayer is equipped with 12 nozzles spaced 50 cm (20 inches) apart. The sprayer flow rate is set to provide an application rate of 280 l/ha (30 gal/ac). The product must be applied such that 4 kg/ha (3.5 lb/acre) of active ingredient is applied on the field. The ground speed is 14.4 km/hr (9 mph). The available nozzle orifice diameter is 2.0 mm (0.08 in) and is this capable of providing 3 l/min (0.80 gal/min) at 300 kPa (40 psi). (Note 128 fluid oz = 1 gal)

a) What is the ratio of active ingredient to water in the spray mixture (i.e kg active ingredient per litre or water or lbs active ingredient per gal of water

b) What is the required flow rate from each nozzle in liters per minute (gal/min)?

c) What pressure is required at the nozzle to obtain the correct flowrate.

c) What is the total pump flowrate required for this application rate.

d) Assuming that the full sprayer tank holds 2000 L gallons (500), determine the minimum re circulation flowrate required for hydraulic agitation of the tank for oil-water emulsions (10% oil).

e) Assume that the pump operates at a pressure of 400 kPa (60 psi) before the pressure regulation to control nozzle flowrate. The volumetric efficiency of the pump is 0.70 and the mechanical efficiency is 0.85. What is the power required to drive the pump?

After a period of operation the pressure regulation device is operating incorrectly and increases pressure by 20%.

e) What is the new flow rate at the higher pressure in liters per minute (gal/min)?

f) What is the new volume median diameter of the spray droplets.

Question 2: A sprayer is required to provide a total application rate of 200 liters per hectare (20 gal/a), at a ground speed of 21.6 km/hr (13.5 mph), with 50 cm (20 in) nozzle spacing, and a 27m (90ft) swath width. The available nozzle orifice diameter is 1.0 mm (0.04 in) and is this capable of providing 3.0 l/min (0.8 gal/min) at 300 kPa (40 psi). At this pressure the volume median diameters of the spray droplets are 300 μm (0.010 in).

a) What is the required flow rate from each nozzle in liters per minute (gal/min)?

b) What pressure is required at the nozzle to obtain the correct flowrate.

c) Assuming that the full sprayer tank holds 2000 L gallons (500), determine the minimum re circulation flowrate required for hydraulic agitation of the tank for oil-water emulsions (10% oil), at the pump pressure of 50 kPa (80 psi).

d) Assume that the pump operates at a pressure of 50 kPa (80 psi) before the pressure regulation to control nozzle flowrate. The volumetric efficiency of the pump is 0.70 and the mechanical efficiency is 0.85. What is the total power required to drive the pump?

After a period of operation the orifice diameter increases by 15%.

e) What is the new flow rate from each worn nozzle in liters per minute (gal/min)?

f) What is the new volume median diameter of the spray droplets.

g) What is the application rate for the worn nozzles.

f) On a spray table, the following "normalized" distribution data was collected for one of these nozzles, in 5cm length increments: Determine the coefficient of variation for the "whole" sprayer assuming all nozzles are identical, and on a 40 cm (16 in) spacing.

	Distance from Center of Nozzle														
cm	35	30	25	20	15	10	5	0	5	10	15	20	25	30	35
(in)	14	12	10	8	6	4	2	0	2	4	6	8	10	12	14
Application Vol. (Single)	0	0.2	0.4	0.6	0.8	1.0	1.0	1.0	1.0	1.0	0.8	0.6	0.4	0.2	0

Additional Note: You must understand how to calculated different Number, surface and volume mean diameters given a particular set of data

Question 3: Assume an cotton plant with stem diameter 12.00 mm and the ultimate tensile strength is 70 N/mm^2 is to being cut 60 mm above the ground. The plant roots have sufficient strength to fix the stem to the ground and the knife loads the stem as a cantilever beam.

a) Determine the knife force required to load the plant fibers to their ultimate stress.

b) If the modulus of elasticity of the stem is 2000 N/mm^2, determine the maximum horizontal deflection of the plant at the point of failure.

The mass of the plant above the cut is 0.5 kg and cutting occurs when the knife pressure is 30 N/mm^2. The knife bevel angle is 15 degrees and the clearance angle is 5 degrees, with an edge radius of 0.25 mm. The bulk modulus of the material 20 N/mm^2 and co-efficient of friction 0.4. Assume the exponent =2.

Question 4: A forage harvester is to harvest silage, with a yield of 10 Mg/ha, cutting a 1.5 m swath. The harvester has 8 knives and the rotational speed of the cutter is 900 rpm. The nominal required cut length is 5 mm. The diameter of the cutter head is 400mm and is 200 mm wide. The compressed corn silage density is 350 kg/m^3, and the specific cutting energy is 15 J.m/kg. The coefficient of friction between the forage and housing is 0.5 and the material travels in a 120 arc before exiting the housing.

a) Calculate the peripheral speed required for the feed rolls into the cutter head.

b) If the thickness of the material mat flowing into the cutter head is 125 mm what is the harvest speed.

c) Determine the total power requirements for this forage harvester under these conditions, accounting for all the different power consuming processes (Clearly identify for any assumed values).

d) If the maximum feedrate capacity of the cutterhead (5 mm cut length) is 8.4 kg/s what is the maximum height of the inlet opening to the cutter head?

e) What is the maximum forward travel velocity that can be achieved at this feedrate.

Question 5: **Part A)** A sickle section has an oblique angle of 25 degrees when the forward speed of the mower is zero. The corresponding counter shear oblique angle is 15 degrees. The friction coefficient for both surfaces are 0.364.

i). Determine the clip angle assuming a travel speed of zero.

ii). Determine the clip angle at which sliding of the plant along the knife edges is to be expected..

Assuming that the knife operates in a sinusoidal motion, with a knife stroke of 76.2mm and a frequency of 500 rad/s.

iii). Determine maximum velocity of the knife relative to the mower.

iv). If the mover is traveling at 5 m/s find the oblique clip angle for the knife at the maximum knife velocity.

Question 6: The following data was collected from a field test for corn with a 8 row rotary self-propelled combine, (0.762m or 30 in rows). The gross yield on the field was 10 Mg/ha (160 bu/acre) and the MOG/Grain ratio during harvest was 0.50. The combine traveled at 7.2 km/h (4.5 mph). The measured losses were as follows:

Preharvest Loss 0.75%, Header Loss 0.1%, Threshing Losses 1.25%, Cleaning Losses 2%

Determine the following information

(a) The total mass of grain per hectare (acre) on the ground prior to harvest.

(b) The total mass of grain per hectare (acre) on the ground after header passes over the ground

(c) The total mass of grain per hectare (acre) on the ground after the combine passes over the ground

(d) The mass flowrate of unthreshed corn leaving the rear of the combine

(e) The mass flowrate of threshed corn leaving the rear of the combine

(f) The mass flowrate of corn measured by a grain yield monitor entering the grain bin.

Question 7: A combine fitted with a 12 row corn head (0.762m or 30 inch rows) is used to harvest corn at 7.2 kph (4.5 mph). The MOG feedrate is 350 kg/min (160 lb/min) and the MOG/grain ratio is 0.25. Assume that 75% of the grain is separated by the cylinder.

(i) Determine the grain flowrate into the combine, and corn yield.

(ii) If the separation losses in the straw walkers is 10 percent what is the total separation losses, in percent

(ii). Calculate the length of the length of the straw walker required to achieve grain separation losses reported above.

(iii). If the combine is fitted with a 2.0 m long straw walker determine the expected separator loss as a percentage of total grain flow.

(iv). If the corn price is $118/tonne ($3.00 bu), calculate the cost of the lost grain in terms of dollars per hectare (acre).

(v) If the MOG/grain ratio is increased to 0.40, without changes in field yield (MOG feed rate changes), what would be the expected separator loss as a percentage of total grain flow with a 2.0 m long straw walker.