**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. Do not spend all your time on one question, come back to it at the end.

The following Equations are given:

Power = $2\pi * T * N / 60{,}000$ (kW) Power = $2\pi * T * N / 33{,}000$ (Hp)

Planetary Gears

$(N_s - N_c)/(N_r - N_c) = -(n_r/n_s)$

**Traction Equations:**

$\mu_g = F/W = 0.75(1 - \exp[-0.3C_nS])$

$\rho = TF/W = 1.2/C_n + 0.04$

$C_n = CI*bd/W$

Slip or TR = $100*(1 - V_a / V_o)$

$TE = P_{db} / P_a$

$TE = (F_{db}*V_a)/P_a$

Traction/Weight Transfer

$W*X_{cg} = R_f*WB + F_{db}*Z_r$ $R_r*WB = W*(WB-X_{cg}) + F_{db}*Z_f$

Sideways Overturns

$V_c = [(g * r * Y_{cg})/Z_{cg}]^{1/2}$ (Note: This equation is only valid on a flat surface)

Hydraulics. The equations below are given without units, and may require unit conversions

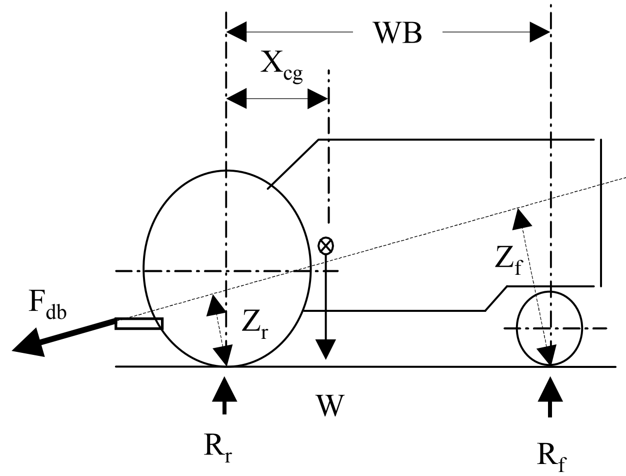
| | | | |
|---|---|---|---|
| Force | $F = p*A$ | | |
| Flowrate | $Q = V*A$ | | |
| Flowrate, | $Q_{Theoretical} = D*N$ | | |
| Torque, | $T_{Theoretical} = \Delta p*D/2\pi$ | $T = \Delta p*D/2\pi$ | $T = \Delta p*D/2\pi*1/12$ |
| Power, | $P = \Delta p*Q$ | $P = \Delta p*Q/60$ | $P = \Delta p*Q*231*1/12*1/33000$ |

Note: F= force, P=Power, Q=Flowrate, p=pressure, T=Torque, N=rpm, V=velocity, S = Speed
SRAF is defined as the Static Rear Axle Force

Units Conversions

| | |
|---|---|
| 1 inch = 0.0254 meters | 1 gal = 231 cubic inches |
| 1 ft = 0.3048 meters | 33000 ft.lb/min = 1 Hp |
| 1 pound force = 4.45 Newton | 1 mile = 5280 ft |
| 1 psi = 6.8948 kPa | |
| 1 Hp = 0.7457 kW | 1000 liters = 1 $m^3$ |
| 1 ft.lb = 1.356 N.m | 1000 $cm^3$ = 1 liter |
| 1 gal = 3.785 liters | Force (N)=mass(kg)*gravity($m/s^2$) 1 (N)= 1 (kg) * g ($m/s^2$) |

**Question 1**




Given the following information for the tractor shown

Static Weight (zero drawbar pull)

Total Mass Tractor (english) 25,000 lb

Total Mass Tractor (metric) (11,250 kg = 112.50 kN force)
(Assuming Gravity = 10m/s$^2$)

Wheelbase 120" (3000 mm)

Tread Width 60" (1500mm)

Given the following $Z_r$= 40" (1000mm) and $Z_f$=120" (3000mm)

a) i) If a drawbar force of 21000lb (94.5kN) results in the front tire just lifting off the ground (Rf=0). Determine the horizontal distance from the center of the rear axle to the center of gravity of the tractor (Xcg).

ii) What was the static reaction force on the front axle with zero pull.

iii) What was the static reaction force on the rear axle (zero pull).

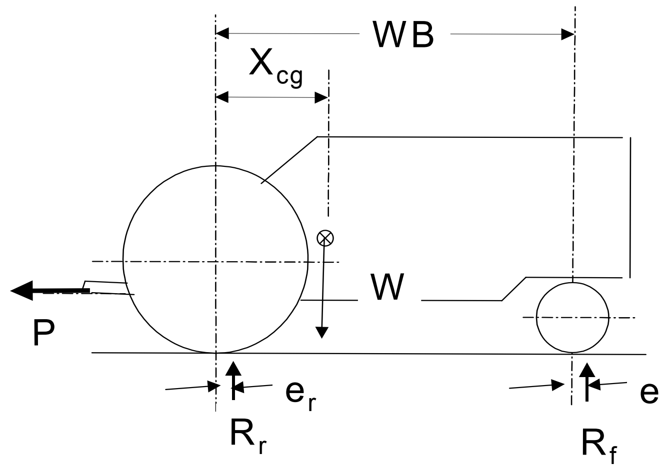
b) For a drawbar force of $F_{db}$ = 15000 lb. (67.5kN)

i) Determine the dynamic weight on the front axle

ii). Determine the dynamic weight on the rear axle

**Question 2(25 points)**

Given the following information for the tractor shown:




<u>Static Weight on Tires</u> (zero drawbar pull)

| | Ballasted Weight |
|---|---|
| Rear Axle Weight | 25000 lb (11000 kg) |
| Front Axle Weight | 6000 lb (3000 kg) |
| Total Weight | 31000 lb (14000 kg) |

| <u>Rear Tire Dimensions</u> | <u>Front Tire Dimensions</u> |
|---|---|
| b = 19.2" (488mm) | b = 14" (355mm) |
| d = 64.8" (1645 mm) | d = 30" (785 mm) |
| Rolling Radius = 30" (785) | |
| Wheelbase | 112" (2845 mm) |
| Drawbar Height | 20" (500mm) |

Given the horizontal pull P, on the drawbar is 12,500 lb. (55000N) for an ballasted tractor, 2 wheel drive tractor.

i). Determine Dynamic Weight on each of the front and rear tires. You may assume that reaction forces are directly below the axle of the respective wheels.

b) If the tractor is operating on soil with a cone index of 150 psi (100 $N/cm^2$). Use the **<u>Wismer-Luth Equations</u>** to:

(i) Determine the towed force (TF) for required to move the front tire through the soil.

(ii) Determine the towed force (TF) for required to move the rear tire through the soil.

(ii) The Gross Tractive Force (F) required per driving tire.

(iii) Calculate the Travel Reduction (or wheel slip) required to generate the Gross Tractive force required to develop the drawbar pull.

**Question 3**

Travel Reduction: $TR = 100*(1- S_a / S_o)$ Tractive Efficiency $TE = P_{db} / P_a$

Drawbar Power & Tractive Efficiency $TE = ( F_{db} * S_a )/P_a$

Given the following information for a tractor:

| | Ballasted Weight |
|---|---|
| Rear Axle Weight | 16304 lb (7300 kg) (Assume $g=10\ m/s^2$ to convert from kg to N if you use metric units) |
| Front Axle Weight | 5000 lb (2250 kg) |

From Nebraska Test:

The following data was reported from the maximum drawbar performance test for this tractor under ballast on a concrete surface.

| | | |
|---|---|---|
| **Drawbar Power** | 200 Hp | (150kW); |
| **Actual Speed** | 7.6 mph | (9.5 km/h) |
| **Slip** | 5% | |

a). Determine the travel speed under no load.

b) If this above test was conducted on concrete find the Tractive Efficiency for this test, from the ZOZ chart. (Show all lines on the Chart)

c). Determine the SRAF/axle power.

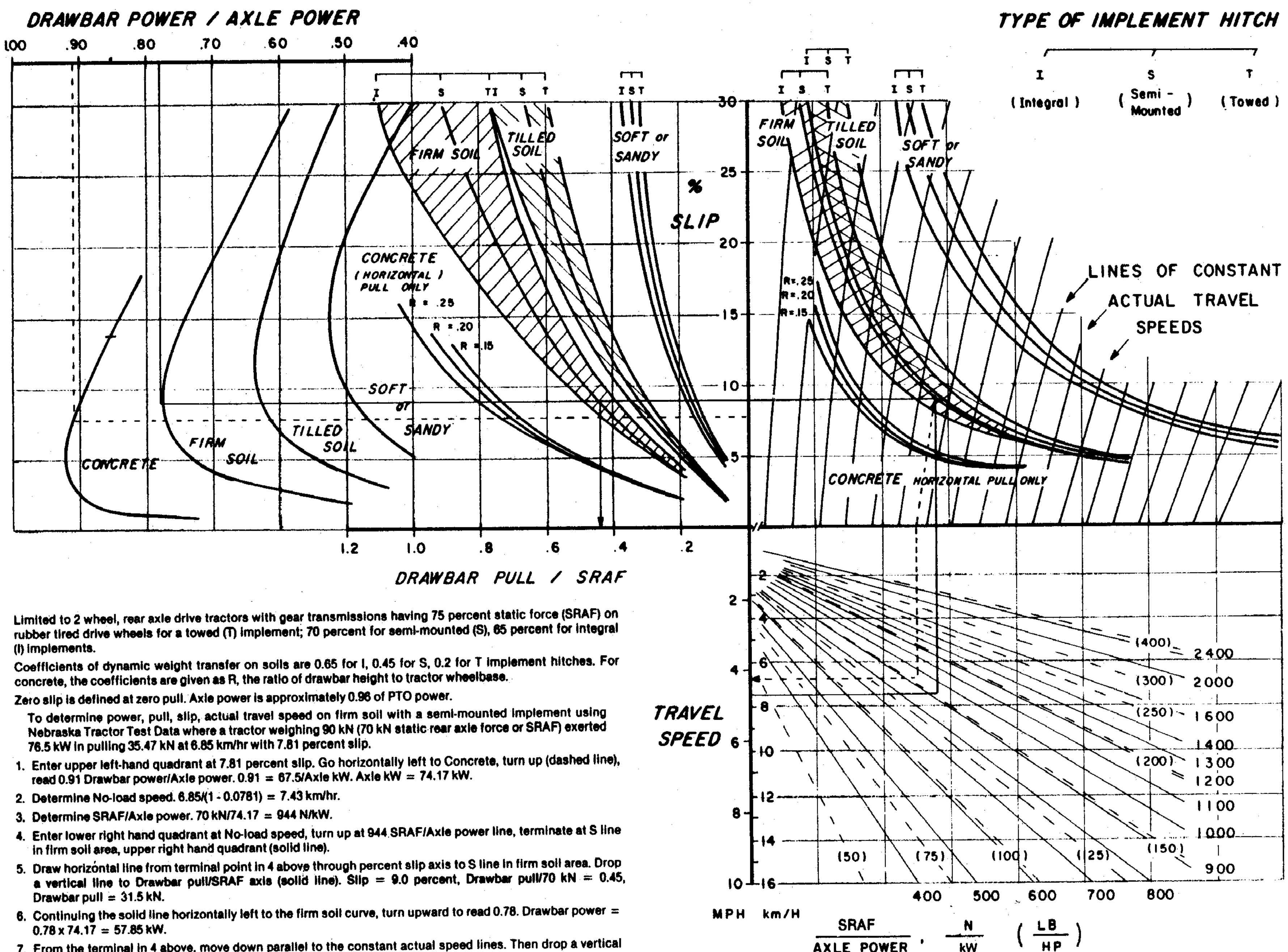
d). This tractor is to be used in the field with full ballast, to pull a semi-mounted plough in tilled soil, in the same gear as above. Using the ZOZ Chart find: (Show all lines on the ZOZ chart)

i) the travel reduction or slip,

ii). Tractive efficiency for the tractor in the field.

iii) Calculate the actual <u>travel speed</u> and <u>drawbar power</u> in the field under these conditions

iv) Find the drawbar pull




Limited to 2 wheel, rear axle drive tractors with gear transmissions having 75 percent static force (SRAF) on rubber tired drive wheels for a towed (T) implement; 70 percent for semi-mounted (S), 65 percent for integral (I) implements.

Coefficients of dynamic weight transfer on soils are 0.65 for I, 0.45 for S, 0.2 for T implement hitches. For concrete, the coefficients are given as R, the ratio of drawbar height to tractor wheelbase.

Zero slip is defined at zero pull. Axle power is approximately 0.96 of PTO power.

To determine power, pull, slip, actual travel speed on firm soil with a semi-mounted implement using Nebraska Tractor Test Data where a tractor weighing 90 kN (70 kN static rear axle force or SRAF) exerted 76.5 kW in pulling 35.47 kN at 6.85 km/hr with 7.81 percent slip.

1. Enter upper left-hand quadrant at 7.81 percent slip. Go horizontally left to Concrete, turn up (dashed line), read 0.91 Drawbar power/Axle power. 0.91 = 67.5/Axle kW. Axle kW = 74.17 kW.
2. Determine No-load speed. 6.85/(1 - 0.0781) = 7.43 km/hr.
3. Determine SRAF/Axle power. 70 kN/74.17 = 944 N/kW.
4. Enter lower right hand quadrant at No-load speed, turn up at 944 SRAF/Axle power line, terminate at S line in firm soil area, upper right hand quadrant (solid line).
5. Draw horizontal line from terminal point in 4 above through percent slip axis to S line in firm soil area. Drop a vertical line to Drawbar pull/SRAF axis (solid line). Slip = 9.0 percent, Drawbar pull/70 kN = 0.45, Drawbar pull = 31.5 kN.
6. Continuing the solid line horizontally left to the firm soil curve, turn upward to read 0.78. Drawbar power = 0.78 x 74.17 = 57.85 kW.
7. From the terminal in 4 above, move down parallel to the constant actual speed lines. Then drop a vertical to the 944 SRAF/Axle power turning line, go left, and read 6.8 km/hr actual speed (dashed line).

**FIGURE 16.9** Traction prediction chart (Reprinted from ASAE Data D230.4, *Agricultural machinery management*, revised December 1983)

**Question 4 (25 points)**

The following specifications for a certain pump and motor combination were given:

| | |
|---|---|
| **Pump** | |
| Displacement | 90 $cm^3$/rev (5.5 $in^3$/rev) |
| Rated Speed | 2400 rpm |
| Rate Pressure | 20.7 MPa (3000 psi) |
| Rated Delivery | 210 l/min (55 gal/min) @ rated speed |
| Power Input | 80.0 kW (110 Hp) @ rated delivery and speed |
| **Motor** | |
| Displacement | 130 $cm^3$/rev ( 8$in^3$/rev) |
| Volumetric Efficiency | 0.9 |
| Mechanical Efficiency | 0.95 |

i). Determine the volumetric efficiency of the pump.

ii) Determine the mechanical efficiency of the pump.

iii). Determine the output torque from the motor shaft.

iv) Calculate the actual speed of rotation of the motor.

(v) Determine the actual power output from the motor.

(vi) Calculate the overall efficiency of the system.

**Question 5 (25 points)**

A certain hydraulic pump and motor combination is tested operating at a maximum system pressure of 20.7 Mpa (3000 psi). There is a 1.7 MPa (250 psi) total line pressure loss between the hydraulic pump and motor units. During tests the following information is given or recorded.

**Hydraulic Motor**

| | | |
|---|---|---|
| Motor Output Speed | 1500 rpm | |
| Motor Inlet Pressure | 19 MPa (2750 psi) | Motor Mechanical Efficiency = 0.9 |
| Motor Displacement | 130 $cm^3$/rev ( 8$in^3$/rev) | Motor Volumetric Efficiency = 0.85 |

**Hydraulic Pump**

| | | |
|---|---|---|
| Pump Outlet Pressure | 20.7 MPa (3000 psi) | Pump Mechanical Efficiency = 0.92 |
| Pump Displacement | 90 $cm^3$/rev (5.5 $in^3$/rev) | Pump Volumetric Efficiency = 0.80 |

i). Determine the theoretical output torque from the motor shaft.

ii). Determine the actual output torque from the motor shaft.

iii). Determine the actual power output from the motor.

iv) Calculate the actual flowrate required into the motor to achieve an output speed of 1500 rpm.

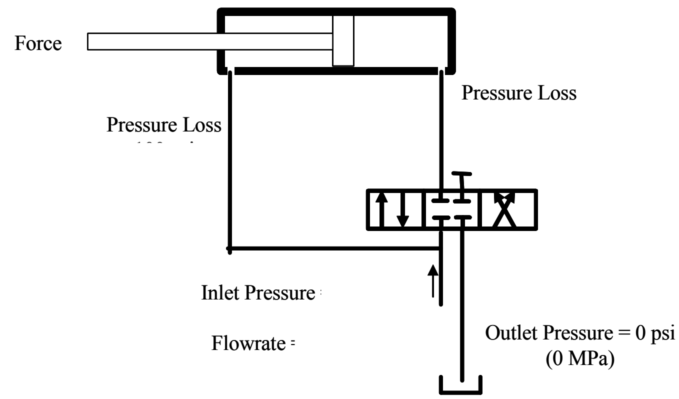
(v) Calculate the actual speed the pump must operate to achieve this flowrate.

(vi) Determine the theoretical input torque into the pump shaft.

(vii) Determine the actual input torque required into the pump shaft.

(viii) Calculate the input power required to drive the pump

**Question 6** Consider the regenerative hydraulic circuit shown on the right.




Given the following information:

Inlet Pressure 2000 psi (13.75 Mpa)
Inlet Flowrate 10 gal/min (38 l/min)
Zero Outlet Pressure

Pressure losses:
In the left-hand line 100 psi ( 700 kPa)
In the right-hand line 250 psi ( 1.75 MPa)

Hydraulic cylinder bore 4" (10 cm)
Cylinder Rod Diameter 2" (5 cm)

a). What is the maximum load that can be moved when the cylinder is extending?

b). What is the maximum load that can be moved when the cylinder is retracting?

c). How fast will the cylinder extend?