

Question 1 Given the following information for a tractor: (Note: Metric values are approximate conversions of the equivalent English values, therefore answers may be slightly different)

Rear Axle Weight	15500 lb (7000 kg)
Front Axle Weight	4500 lb (2000 kg)
Total Weight	20000 lb (9000 kg)
Wheel Base	110" (2800mm)
Center of Gravity	24.75" (622mm)(Distance from rear axle)
Drawbar Height	24" (600mm)

METHOD 1: Weight Transfer used directly (without using Xcg)

a) Determine the weight transfer to the rear wheels if a horizontal pull of 3000 lb (13.2 kN) is attached to the drawbar.

$$\begin{aligned} \nabla R_r &= P * Z_f / WB \\ &= 3000 * 24 / 110 \\ &= \mathbf{654 \text{ lb.}} \end{aligned}$$

b) Under these conditions, is the weight transfer from the front wheels equal to the weight transfer to the back wheels.

Since the pull is horizontal then this will be the same as the rear.

c) Determine the horizontal pull required for the front wheels to begin lifting of the ground.

To lift of the ground the weight transfer must equal the static weight on the front tire (i.e $\nabla R_r = 4500$).

$$\begin{aligned} \nabla R_r &= P * Z_r / WB \\ P &= \nabla R_r * WB / Z_r \\ &= 4500 * 110 / 24 \\ &= \mathbf{20625 \text{ lb}} \end{aligned}$$

METHOD 2: Dynamic weight calculated and then weight transfer calculated

a) Determine the weight transfer to the rear wheels if a horizontal pull of 3000 lb (13.2 kN) is attached to the drawbar.

$$\begin{aligned} R_r &= W * (WB - X_{cg}) / WB + P * Z_f / WB \\ &= 20000 * (110 - 24.75) / 110 + 3000 * 24 / 110 \\ &= \mathbf{16 \ 154 \text{ lb.}} \end{aligned}$$

$$\begin{aligned} \nabla R_r &= R_r - R_r' \\ &= 15745 - 15500 \\ &= \mathbf{654 \text{ lb}} \end{aligned}$$

b) Under these conditions, is the weight transfer from the front wheels equal to the weight transfer to the back wheels.

Since the pull is horizontal then this will be the same as the rear.

c) Determine the horizontal pull required for the front wheels to begin lifting of the ground.

To lift of the ground the weight transfer must equal the static weight on the front tire (i.e $\nabla R_r = 4500$).

$$\begin{aligned} R_r &= W * (X_{cg}) / WB - P * Z_r / WB \\ 0 &= W * (X_{cg}) / WB - P * Z_r / WB \\ P &= W * (X_{cg}) / WB / [Z_r / WB] \\ P &= W * (X_{cg}) / Z_r \\ &= 20000 * 24.75 / 24 \\ &= \mathbf{20625 \text{ lb}} \end{aligned}$$

Question 3 A double acting hydraulic cylinder has a bore diameter of 4", a rod diameter of 2". The maximum pump pressure is 2200 psi. One cylinder port is connected to the pump, and the return line feeds directly into the reservoir. Assume a pressure drop of 100 psi in both the pressure and return line to the cylinder. Pump delivery rate is 20 gal/min

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

$$\begin{aligned} \text{Max Force} &= P_1 \cdot A_1 - P_2 \cdot A_2 \\ &= [(2200-100) \cdot \pi/4 \cdot 4^2] - [(100) \cdot \pi/4 \cdot (4^2-2^2)] \\ &= 26389 - 942 \\ &= \underline{\underline{25447 \text{ lb}}} \end{aligned}$$

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

$$\begin{aligned} \text{Max Force} &= P_2 \cdot A_2 - P_1 \cdot A_1 \\ &= [(2200-100) \cdot \pi/4 \cdot (4^2-2^2)] - [(100) \cdot \pi/4 \cdot (4^2)] \\ &= 19792 - 1257 \\ &= \underline{\underline{18535 \text{ lb}}} \end{aligned}$$

c). How fast will the cylinder extend.

$$\begin{aligned} \text{Velocity} &= Q(\text{gal/min}) \cdot 231(\text{in}^3/\text{gal}) / A_1 \\ &= 20 \cdot 231 / (\pi/4 \cdot 4^2) \\ &= \underline{\underline{368 \text{ in/min}}} \end{aligned}$$

d). How fast will the cylinder retract.

$$\begin{aligned} \text{Velocity} &= Q(\text{gal/min}) \cdot 231(\text{in}^3/\text{gal}) / A_2 \\ &= 20 \cdot 231 / (\pi/4 \cdot (4^2-2^2)) \\ &= \underline{\underline{490 \text{ in/min}}} \end{aligned}$$

e). What is the flowrate of oil from the cylinder when it is retracting.

$$\begin{aligned} Q(\text{out}) &= Q(\text{in}) \cdot A_1/A_2 \\ &= 20 \cdot (\pi/4 \cdot 4^2) / (\pi/4 \cdot (4^2-2^2)) \\ &= \underline{\underline{26.667 \text{ gal/min}}} \end{aligned}$$

OR

$$\begin{aligned} Q(\text{out}) &= \text{Velocity} \cdot A_1/231 \\ &= 490 \cdot (\pi/4 \cdot 4^2) / 231 \\ &= \underline{\underline{26.667 \text{ gal/min}}} \end{aligned}$$

Question 4 Given the following specifications for a gear pump listed in a catalog.

Displacement = 1.8 in³/rev (29.5 cm³/rev)

Rate Speed = 2500 rpm

Rated Pressure = 3000 psi (20.7 Mpa)

Rated Delivery = 18 gal/min (68.13 l/min)

Power Input = 38 Hp (28.35 kW)

a). Calculate theoretical delivery.

$$\begin{aligned} Q_t &= D * N / 231 \\ &= 1.8 * 2500 / 231 \\ &= \mathbf{19.48 \text{ gal/min}} \end{aligned}$$

b). What is the volumetric efficiency?

$$\begin{aligned} \text{Vol. Eff} &= Q_a / Q_t \\ &= 18 / 19.48 \\ &= \mathbf{.924} \end{aligned}$$

c). What is the actual input Torque?

$$\begin{aligned} T &= P * 33000 / 2\pi N \\ &= 38 * 33000 / (2\pi * 2500) \\ &= \mathbf{79.8 \text{ ft.lb}} \end{aligned}$$

d). What is the theoretical input Torque?

$$\begin{aligned} T &= D * P / 2\pi / 12 \\ &= 1.8 * 3000 / 2\pi / 12 \\ &= \mathbf{71.6 \text{ ft.lb}} \end{aligned}$$

e). Calculate the overall efficiency of the pump.

$$\begin{aligned} \text{Overall} &= \text{vol eff} * \text{mech. Eff} \\ &= .924 * .897 \\ &= \mathbf{0.83} \end{aligned}$$

f). What is the mechanical efficiency.

$$\begin{aligned} \text{Mechanical Eff.} &= T_t / T_a \\ &= 71.6 / 79.8 \\ &= \mathbf{0.897} \end{aligned}$$

Question 5 Given the following specifications for a motor listed in a catalog.

Displacement = 4 in³/rev (65.5 cm³/rev)

Rate Speed = 1800 rpm

Rated Pressure = 3000 psi (20.7 Mpa)

Required Delivery = 35 gal/min (130 l/min)

Power Output = 48 Hp (35.8 kW)

a). Calculate theoretical flowrate for the motor at rated speed.

$$\begin{aligned} Q_t &= D * N / 231 \\ &= 4 * 1800 / 231 \\ &= \underline{\underline{31.2 \text{ gal/min}}} \end{aligned}$$

b). What is the volumetric efficiency?

$$\begin{aligned} \text{Vol. Eff} &= Q_t / Q_a \\ &= 31.2 / 35 \\ &= 0.89 \end{aligned}$$

c). What is the actual output Torque?

$$\begin{aligned} T &= P * 33000 / 2\pi N \\ &= 48 * 33000 / (2\pi * 1800) \\ &= \underline{\underline{140 \text{ ft.lb}}} \end{aligned}$$

d). What is the theoretical output Torque .

$$\begin{aligned} T &= D * P / 2\pi / 12 \\ &= 4 * 3000 / 2\pi / 12 \\ &= \underline{\underline{159 \text{ ft.lb}}} \end{aligned}$$

e). Calculate the overall efficiency of the motor.

$$\begin{aligned} \text{Overall eff.} &= 0.88 * 0.89 \\ &= \underline{\underline{0.78}} \end{aligned}$$

f). Determine the mechanical efficiency of the motor.

$$\begin{aligned} \text{Mech. Eff} &= T_a / T_t \\ &= 140 / 159 \\ &= \underline{\underline{0.88}} \end{aligned}$$

NEBRASKA TRACTOR TEST 1525 — CASE 2094 POWERSHIFT DIESEL 12 SPEED

POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crank shaft speed rpm	Fuel Consumption		Temperature °F (°C)			Barometer inch Hg (kPa)		
		gal/hr (l/h)	lb/hp-hr (kg/kW-h)	Hp-hr/gal (kW-h/l)	Cooling medium	Air wet bulb		Air dry bulb	
MAXIMUM POWER AND FUEL CONSUMPTION									
Rated Engine Speed—Two Hours (PTO Speed—998 rpm)									
110.50 (82.40)	2100	7.175 (27.157)	0.455 (0.276)	15.40 (3.034)	187 (86.1)	65 (18.3)	75 (23.8)	28.96 (97.80)	
VARYING POWER AND FUEL CONSUMPTION—Two Hours									
97.14 (72.44)	2170	6.561 (24.837)	0.473 (0.288)	14.80 (2.916)	184 (84.2)	65 (18.3)	74 (23.3)	.....
0.00 (0.00)	2302	2.310 (8.744)	.....	.....	174 (78.9)	66 (18.9)	75 (23.9)	.....
49.97 (37.26)	2236	4.341 (16.434)	0.608 (0.370)	11.51 (2.267)	181 (82.8)	66 (18.6)	76 (24.2)	.....
111.42 (83.09)	2100	7.230 (27.368)	0.454 (0.276)	15.41 (3.036)	187 (86.1)	66 (18.6)	75 (23.6)	.....
25.33 (18.99)	2266	3.373 (12.767)	0.992 (0.567)	7.51 (1.480)	175 (79.4)	65 (18.3)	74 (23.1)	.....
73.99 (55.17)	2205	5.366 (20.311)	0.508 (0.309)	13.79 (2.716)	183 (83.6)	66 (18.9)	75 (23.9)	.....
Av Av	59.64 (44.47)	2213	4.864 (18.410)	0.571 (0.347)	12.26 (2.416)	181 (82.5)	66 (18.6)	75 (23.7)	28.94 (97.73)

DRAWBAR PERFORMANCE

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank- shaft speed rpm	Slip %	Fuel Consumption		Temp. °F (°C)			Barom. inch Hg (kPa)	
					gal/hr (l/h)	lb/hp-hr (kg/kW-h)	Hp-hr/gal (kW-h/l)	Cool- ing med	Air wet bulb		Air dry bulb
Maximum Available Power—Two Hours 8th (3-2) Gear											
98.66 (73.37)	5851 (26.02)	6.32 (10.18)	2099	4.45	7.143 (27.039)	0.507 (0.308)	13.81 (2.721)	192 (88.6)	70 (21.1)	76 (24.2)	29.03 (98.01)
75% of Pull at Maximum Power—Ten Hours 8th (3-2) Gear											
79.36 (59.18)	4443 (19.76)	6.70 (10.78)	2195	3.26	6.136 (23.226)	0.541 (0.329)	12.93 (2.548)	190 (87.6)	70 (20.9)	74 (23.2)	28.86 (97.44)
50% of Pull at Maximum Power—Two Hours 8th (3-2) Gear											
54.15 (40.38)	2962 (13.18)	6.86 (11.03)	2219	2.05	4.807 (18.197)	0.621 (0.378)	11.27 (2.219)	188 (86.4)	73 (22.8)	82 (27.5)	28.87 (97.47)
50% of Pull at Reduced Engine Speed—Two Hours 10th (4-1) Gear											
54.20 (40.41)	2962 (13.18)	6.86 (11.04)	1456	2.09	3.850 (14.574)	0.497 (0.302)	14.08 (2.773)	189 (86.9)	73 (22.5)	83 (28.1)	28.83 (97.34)
MAXIMUM POWER IN SELECTED GEARS											
90.78 (67.69)	11910 (52.98)	2.86 (4.60)	2126	14.83	4th (2-1) Gear		189 (87.2)	68 (20.0)	70 (21.1)	29.00 (97.93)	
98.04 (73.11)	8979 (39.94)	4.09 (6.59)	2101	7.18	5th (2-2) Gear		191 (88.3)	70 (21.1)	74 (23.3)	28.91 (97.62)	
99.08 (73.88)	7975 (35.47)	4.66 (7.50)	2101	6.08	6th (3-1) Gear		192 (88.6)	70 (21.1)	74 (23.3)	28.91 (97.62)	
98.50 (73.45)	7068 (31.44)	5.23 (8.41)	2101	5.33	7th (2-3) Gear		192 (88.9)	70 (21.1)	75 (23.9)	28.91 (97.62)	
100.12 (74.66)	5924 (26.35)	6.34 (10.20)	2100	4.34	8th (3-2) Gear		192 (88.9)	70 (21.1)	75 (23.9)	28.90 (97.59)	
98.64 (73.55)	4619 (20.54)	8.01 (12.89)	2099	3.25	9th (3-3) Gear		193 (89.2)	70 (21.1)	75 (23.9)	28.90 (97.59)	
LUGGING ABILITY IN 8th (3-2) GEAR											
Crankshaft Speed rpm		2100	1892	1683	1472	1255	1053				
Pull—lbs (kN)		5924 (26.35)	6436 (28.85)	6756 (30.28)	6827 (30.60)	6689 (29.98)	6349 (28.46)				
Increase in Pull %		0	9	14	15	13	7				
Power—Hp (kW)		100.12 (74.66)	97.50 (72.71)	90.84 (67.74)	80.18 (59.79)	67.10 (50.03)	53.52 (39.91)				
Speed—Mph (km/h)		6.34 (10.20)	5.68 (9.14)	5.04 (8.12)	4.40 (7.09)	3.76 (6.05)	3.16 (5.09)				
Slip %		4.34	4.80	4.95	5.10	4.95	4.80				

TRACTOR SOUND LEVEL WITH CAB	dB(A)
Maximum Available Power—Two Hours	77.5
75% of Pull at Maximum Power—Ten Hours	77.0
50% of Pull at Maximum Power—Two Hours	77.5
50% of Pull at Reduced Engine Speed—Two Hours	74.5
Bystander in 12th (4-3) gear	88.0

TIRES, BALLAST AND WEIGHT	With Ballast	Without Ballast
Rear Tires	—No., size, ply & psi (kPa)	
Ballast	Inner Two 18.4-38; 8; 14 (95)	Inner Two 18.4-38; 8; 14 (95)
Ballast	Outer Two 18.4-38; 6; 14 (95)	Outer Two 18.4-38; 6; 14 (95)
Ballast	None	None
Ballast	78 lb (35 kg)	None
Front Tires	—No., size, ply & psi (kPa)	
Ballast	Two 11.00-16; 8; 40 (275)	Two 11.00-16; 8; 40 (275)
Ballast	None	None
Ballast	125 lb (57 kg)	None
Height of Drawbar	19.5 in (495 mm)	19.5 in (495 mm)
Static Weight with Operator—Rear	11230 lb (5094 kg)	10920 lb (4953 kg)
—Front	3520 lb (1597 kg)	3270 lb (1483 kg)
—Total	14750 lb (6691 kg)	14190 lb (6436 kg)

Department of Agricultural Engineering

Dates of Test: May 30 to June 16, 1984

Manufacturer: J. I. CASE COMPANY, 700 State Street, Racine, Wisconsin 53404

FUEL, OIL AND TIME: Fuel No. 2 Diesel Cetane No. 46.0 (rating taken from oil company's inspection data) Specific gravity converted to 60°/60° (15°/15°) 0.8408 Fuel weight 7.000 lbs/gal (0.839 kg/l) Oil SAE 30 API service classification SF, CD To motor 4.354 gal (16.481 l) Drained from motor 4.085 gal (15.463 l) Transmission and final drive lubricant Case Powergard PTF transmission fluid Total time engine was operated 40.0 hours.

ENGINE: Make Case Diesel Type six cylinder vertical Serial No. *10356640* Crankshaft lengthwise Rated rpm 2100 Bore and stroke 4.625" x 5.0" (117.5 mm x 127 mm) Compression ratio 16.0 to 1 Displacement 304 cu in (8259 ml) Starting system 12 volt Lubrication pressure Air cleaner two paper elements Oil filter one full flow cartridge Oil cooler radiator for hydraulic and transmission oil Fuel filter two paper cartridges and prestrainer Muffler vertical Cooling medium temperature control two thermostats.

CHASSIS: Type standard with duals Serial No. *9932956* Tread width rear 60" (1524 mm) to 124" (3150 mm) front 60" (1524 mm) to 88" (2235 mm) Wheel base 110" (2794 mm) Center of gravity (without operator or ballast, with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from center-line of rear wheels 25.7" (652 mm) Vertical distance above roadway 40.7" (1034 mm) Horizontal distance from center of rear wheel tread 0" (0 mm) to the right/left Hydraulic control system direct engine drive Transmission selective gear fixed ratio with partial (3) range operator controlled powershift Advertised speeds mph (km/h) first 1.9 (3.1) second 2.5 (4.0) third 3.2 (5.2) fourth 3.2 (5.2) fifth 4.3 (6.9) sixth 4.9 (7.9) seventh 5.4 (8.7) eighth 6.5 (10.5) ninth 8.1 (13.0) tenth 9.9 (15.9) eleventh 13.2 (21.2) twelfth 18.1 (29.1) reverse 3.2 (5.2), 5.4 (8.7), 8.1 (13.0) Clutch wet multiple disc hydraulically power actuated by foot pedal Brakes wet multiple disc hydraulically power actuated by two foot pedals which can be locked together Steering hydrostatic Turning radius (on concrete surface with brake applied) right 161.8" (4.11 m) left 161.8" (4.11 m) (on concrete surface without brake) right 182.2" (4.63 m) left 182.2" (4.63 m) Turning space diameter (on concrete surface with brake applied) right 338" (8.59 m) left 338" (8.59 m) (on concrete surface without brake) right 382.2" (9.71 m) left 382.2" (9.71 m) Power take-off 534 rpm at 2100 engine rpm and 998 rpm at 2100 engine rpm.

REPAIRS AND ADJUSTMENTS: No repairs or adjustments.

REMARKS: All test results were determined from observed data obtained in accordance with SAE and ASAE test codes and the technically equivalent ISO test codes or official Nebraska test procedure. For the maximum power tests, the fuel temperature at the injection pump return was maintained at 180°F (82.2°C). Six gears were chosen between 15% slip and 10 mph (16.1 km/h).

We, the undersigned, certify that this is a true and correct report of official Tractor Test No. 1525, July 19, 1984.

LOUIS I. LEVITICUS
Engineer-in-Charge

K. VON BARGEN
W. E. SPLINTER
T. R. BARNARD