A three throw reciprocatng positive displacement pump has cylinder of 25 cm diameter and stroke of 50 cm each. The pump is required to deliver 100 litres/second at a head of 90 m. Friction losses are estimated to be 1 m in suction pipe and 19 m in delivery pipe. Velocity of water in the delivery pipe is 1 m/s, overall pump efficiency is 85% and the slip is 3%. Determine the speed of pump and the power required to run it.

A three throw pump has three equl cylinders with rams connected to cranks at 120° apart by a common shaft.

D_p	25	cm	0.25	m	
L_p	50	cm	0.5	m	
(hs+hd)	90	m			
Q	100	lit	0.1	m^3/s	
h_{fs}	1	m			
h_{fd}	19	m			
V_d	1	m/s			
ηo	0.85				
S	0.03				$(Q_{th}-Q)/Q_{th}$ or **$Q = (1-S)*Q_{th}$**
γ	9810				$Q_{th}=3*A_pL_pN/60$
$A_p=\pi/4*D_p^2$	0.049	m^2			
Q_{th}	0.001227	*N			$Q_{th}=(3A_pL_p/60)*N$
Q=	0.001227	***N*(1-S)**			
N=	**84.023**	**rpm**			

Total head against which pump has to work

$H=(h_s+h_d)+(h_{fs}+h_{fd})+V_d^2/2g$	**110.05**	**m**
Water Power (γQH)	**107.96**	**kW**

ηo=Water Power/(Power required to drive the shaft or power supplied to shaft)

Power required to drive the shaft =	**127.01**	**kW**

The plunger of a reciprocating pump has an accleration of 2.5 m/s^2 at the end of the stroke, and the sectional area of plunger equals 1.65 times that of delivery pipe. The delivery pipe is 55 m long and it rises upward at a lope of 1 in 5. Find whether separation will take place, if so, at which section of the pipe. Assume simple harmonic motion, and take atmosphere pressure = 10.3 m of water and separation pressure = 2.5 m of water.

l_d	55	m	
$Slope_{ld}$	0.2		
A_p/A_s	1.65		
$\alpha = \omega^2 r$	2.5	m/s^2	
h_{atm}=	10.3	m	
h_{sep}	2.5	m	
delivery head h_d	11	m	
Pressure head due to accleration in delivery side h_{ad}			
$h_{ad}=(l_d/g)*(A_p/A_d)*\omega^2 r(\cos\theta)$			
During delivery possibility of separation is at the end of stroke			
Then angular displacement θ	180	°	
h_{ad}	-23.13	m	
Pressure head at cylinder at the end of delivery stroke			
(h_d+h_{ad}) above atmospheric head=$(h_d+h_{ad})+h_{atm}$=	**-1.83**	**m**	**separation occur**
Let l be the length of the pipe upto the section where the separation occurs $h_d=l*slope_{ld}$			
h_d=	0.2	*l	
$h_{ad}=(l/g)*(A_p/A_d)*\omega^2 r(\cos\theta)$	-0.42	*l	
Limiting condition for separation = $(h_d+h_{ad})+h_{atm}$= h_{sep}			
l =	**35.4**	**m**	

A double acting single cylinder reciprocating pump of 12.5 cm bore and 25 cm stroke runs at 30 rpm. The centre of pump is 4 m above the level of water in the sump and 30 m below the delivery water level. The lengths of the suction and delivery pipes are 6 m and 35 m of the diameter of each pipe is 6 cm. Assuming simple harmonic motion, find the pressure head in meters of water on the piston at the begining, mid and end of suction and delivery strokes. Take atmospheric pressure head = 10.3 m of water and friction coefficient f =0.01 for both pipes. If the mechanical efficiency is 75% calculate the power required to drive the pump. Aslo calculate the maximum head at any instant against which the pump has to work and its corresponding duty.

η_m=	**75 %**	**0.75**	
l_d=	**35 m**		
f	**0.01**		
bore dia d_b=	**12.5 cm**	**0.13 m**	
l_s =	**6 m**		
Suction and deliver pipe dia d_s or d_d=	**6 cm**	**0.06 m**	
N=	**36 rpm**		
Stroke L =	**25 cm**	**0.25 m**	
h_{atm}=	**10.3 m of water**		
h_s=	**4 m of water**		
h_d=	**30 m of water**		

Crank radius r = (L/2)	12.5 cm	0.13 m
Angular velocity ω = (2πN/60)	3.77 rad/s	
Area of plunger Ap= $\pi/4*d_b^2$	0.01227 m^2	
Area of suction and delivery pipe A_s=A_d= $\pi/4*d_s^3$	0.00283 m^3	

Considering suction stroke:		Pressure=γh (Pa, N/m^2)
Accleration head h_{as}=$l_s/g*A_p/A_s*\omega^2 r\cos\theta$ =	4.714 * cosθ	if γ=9810
Friction head h_{fs} = $4fl_s/2gd_s*(A_p/A_s*\omega*r\sin\theta)^2$	0.592 * $\sin^2\theta$	Pr. head 'h' (m of water)
		1 (kgf/cm^2)=10 m of water
At the beginning of stroke, θ	**0 °**	
h_{as} =	4.71 m of water	
h_{fs}=	0.0 m of water	
Pressure head on the piston = $h_{atm}-(h_s+h_{as}+h_{fs})$	1.59 m of water	**absolute**
At the mid of stroke, θ	**90 °**	
h_{as} =	0.0 m of water	
h_{fs}=	0.592 m of water	
Pressure head on the piston = $h_{atm}-(h_s+h_{as}+h_{fs})$	5.71 m of water	**absolute**
At the end of stroke, θ	**180 °**	
h_{as} =	-4.71 m of water	
h_{fs}=	0.0 m of water	
Pressure head on the piston = $h_{atm}-(h_s+h_{as}+h_{fs})$	11.01 m of water	**absolute**

Considering Delivery stroke:

Accleration head, $h_{ad} = l_d/g*A_p/A_d*\omega^2 r\cos\theta$	27.50	* cosθ
Friction head, $h_{fd} = 4fl_d/2gd_d *(A_p/A_d*\omega * r \sin\theta)^2$	3.454	* $\sin^2\theta$
At the beginning of stroke, θ	**0**	°
h_{ad} =	27.50	m of water
h_{fd}=	0.0	m of water
Pressure head on the piston = $h_{atm}+(h_d+h_{ad}+h_{fd})$	67.80	m of water **absolute**
At the mid of stroke, θ	**90**	°
h_{ad} =	0.0	m of water
h_{fd}=	3.454	m of water
Pressure head on the piston = $h_{atm}+(h_d+h_{ad}+h_{fd})$	43.76	m of water **absolute**
At the end of stroke, θ	**180**	°
h_{ad} =	-27.50	m of water
h_{fd}=	0.0	m of water
Pressure head on the piston = $h_{atm}+(h_d+h_{ad}+h_{fd})$	12.80	m of water **absolute**

Work done and Power required

Work Done per second =$W(h_s+h_d+2/3*h_{fs}+2/3*h_{fd})$

Double acting pump W=2wALN/60	36.11	Nm/s	
Work Done per second =	1325.1	Nm/s	
Average work done =	1325.1	W	1.33 kW
Average power required to drive the pump = P/η_m	1.77	kW	

Maximum head against which the pump has to work is larger of $(h_s+h_{fs}+h_d+h_{fd})$

begining position of piston=$(h_s+h_{as}+h_d-h_{ad})$	11.21	m of water	
mid position of piston=$(h_s+h_{fs}+h_d+h_{fd})$	38.046	m of water	
end position of piston=$(h_s+h_{as}+h_d-h_{ad})$	56.79	m of water	
Max Head =	**56.79**	m of water	56.79 *checked ok*
Power deliverd by the pump = W*(max (big, mid, end))	**2050.47**	W	
Power required to drive the pump = P/η_m	2734.0	W	2.73 kW

position	Stroke length	suction	delivery	atm	*head against pump need to work*
beginning	0	1.59	12.80	10.3	**11.21**
mid	0.125	5.707	43.76	10.3	**38.06**
end	0.25	11.01	67.80	10.3	**56.79**

other lines (without friction component -- dotted)

0	1.59	12.80
0.25	11.01	67.80

other lines (vertical)

0	1.59
0	12.80
0.25	11.01
0.25	67.80