(iii) On surface of cylinde

$$\underset{\sim}{u}(a,\theta,z) = -\left(2U\sin\theta + \frac{K}{2\pi a}\right)\underset{\sim}{e}_\theta.$$

Using Bernoulli's equation for a streamline along the cylinder's surface

$$\frac{p}{\rho} + \frac{1}{2}u^2 = \text{const}, \quad \frac{M}{\rho} \text{ say}$$

$$\therefore\ p(a,\theta,z) = M - \tfrac{1}{2}\rho\left(2U\sin\theta + \frac{K}{2\pi a}\right)^2$$

Net horizontal force per unit length of cylinde

$$= \int_{\theta=0}^{\theta=2\pi} -p(a,\theta,z)\, a\cos\theta\, d\theta$$

$$= 0$$

as $\int_0^{2\pi}\cos\theta\,d\theta = 0$, $\int_0^{2\pi}\sin\theta\cos\theta\,d\theta = 0$, $\int_0^{2\pi}\sin^2\theta\cos\theta\,d\theta = 0$

Net vertical force is

$$\int_{\theta=0}^{\theta=2\pi} -p(a,\theta,z)\, a\sin\theta\, d\theta$$

$$= -a\int_{\theta=0}^{\theta=2\pi}\left(M - \tfrac{1}{2}\rho\left(2V\sin\theta + \frac{K}{2\pi a}\right)^2\right)\sin\theta\, d\theta$$

Now $\int_0^{2\pi}\sin\theta\,d\theta = 0$, $\int_0^{2\pi}\sin^2\theta\,d\theta = \pi$, $\int_0^{2\pi}\sin^3\theta\,d\theta = 0$

So net vertical force $= \frac{1}{2}a\rho\frac{2UK}{\pi a}\pi = \rho UK$

i.e. $$\underset{\sim}{F} = \rho UK\underset{\sim}{j}$$

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11 (a) (i) Coefficient of viscometer can not be measured directly.
Theory can only give formulae valid over restricted ranges. Need to calibrate instruments.
As μ depends strongly on temperature, need to keep temperature of fluid constant.

(ii) A sphere is dropped into a cylinde of the flow. By measuring the terminal speed, the coefficient of viscosity can be calculated. (Stoke's theory assumes fluid is of infinite extent and Reynolds number is less than one) Principal disadvantage is that large volume of liquid is necessary which is difficult to keep at constant temperature.

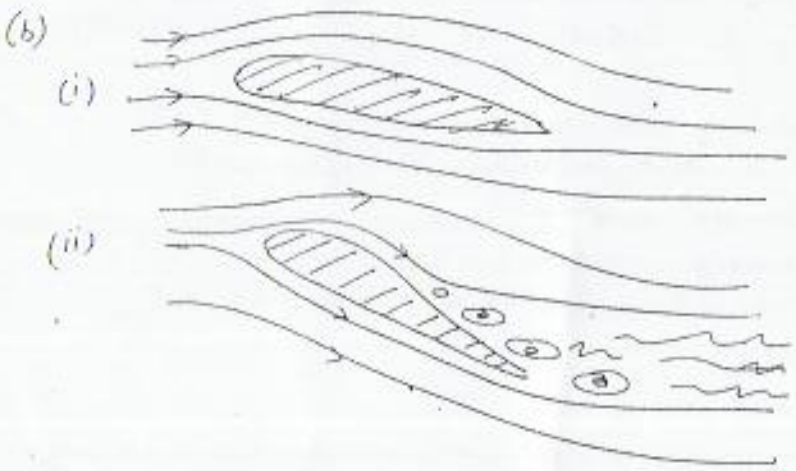
(iii) We use the Hagen-Poiseuille formula

$$\mu = \frac{\pi a^4}{8L}\frac{p - p_0}{Q}$$

for fluid flow thro a pipe. Need to describe one of the following

(a) U-tube (b) horizontal or (c) vertical pipe flow.

(b)



For (ii) the lift force is lower than (i), the boundary layer has separated and the wing is now stalled
An aeroplane may now be falling out of the sky.
This problem can be alleviated by adding