CLASS TEST

SL. 03_SP_ME_ABC_080922

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FLUID MECHANICS

MECHANICAL ENGINEERING

Date of Test : 08/09/2022

ANSWER KEY

1. (d)	7. (c)	13. (c)	19. (a)	25. (b)
2. (c)	8. (d)	14. (c)	20. (b)	26. (a)
3. (c)	9. (a)	15. (c)	21. (d)	27. (c)
4. (d)	10. (c)	16. (d)	22. (a)	28. (d)
5. (a)	11. (a)	17. (d)	23. (b)	29. (d)
6. (c)	12. (b)	18. (b)	24. (c)	30. (c)

DETAILED EXPLANATIONS

1. (d)

The acceleration is not being constant since the force is not constant. The impulse force exerted by the water on the plate is $F = \dot{m}V = (\rho AV)\cdot V = \rho AV^2$, where V is the relative velocity between the water and the plate, which is moving. The magnitude of the plate acceleration is thus a = F/m. But as the plate begins to move, V decreases, so the acceleration must also decrease.

2. (c)

A dimension is a measure of a physical quantity (without numerical values), while a unit is a way to assign a number to that dimension.

3. (c)

$$1 \text{ Poise} = 0.1 \text{ N-s/m}^2$$

$$\text{Shear stress, } \tau = \mu\frac{dv}{dy}$$

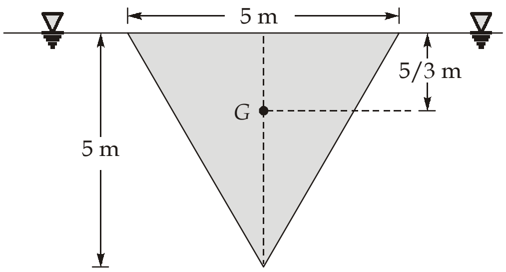
$$\Rightarrow \quad \tau = \left(0.1\times 5\frac{\text{N-s}}{\text{m}^2}\right)\times\left(\frac{5 \text{ m/s}}{0.015 \text{ m}}\right)$$

$$= 166.67 \text{ N/m}^2$$

4. (d)

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0$$

5. (a)



Total pressure on the triangle,

$$F = pA = \gamma h_c A$$

$$= (1000\times 0.75\times 9.81)\times\left(\frac{5}{3}\right)\times\left(\frac{1}{2}\times 5\times 5\right)$$

$$= 750\times 9.81\times\frac{5}{3}\times\frac{25}{2} = 1250\times\frac{25}{2} \simeq 153.28 \text{ kN}$$

6. (c)

As per given data,

$$\text{Gauge pressure} = 350 \text{ kPa}$$

$$\text{Barometric reading} = 740 \text{ mm Hg}$$

$$\rho_{Hg} = 13590 \text{ kg/m}^3$$

The atmospheric (or barometric) pressure can be expressed,

$$P_{atm} = \rho g h = 13.590 \times 9.81 \times 740 \times 10^{-3}$$

$$= 98.655 \text{ kPa}$$

Then the absolute pressure in the tank is

$$P_{abs} = P_{gauge} + P_{atm} = 350 \text{ kPa} + 98.655 \text{ kPa}$$

$$P_{abs} = 448.655 \text{ kPa}$$

7. (c)

Applying Bernoulli's equation between section 1 and 2,

$$\frac{P_1}{\rho g} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + Z_2 + \frac{V_2^2}{2g}$$

$$\Rightarrow \quad 0 + 0 + \frac{V_1^2}{2g} = 0 + (-2) + \frac{(3V_1)^2}{2g} \qquad (\text{as } A_1V_1 = A_2V_2)$$

$$\Rightarrow \quad 2 \times 2 \times 9.81 = 8\, V_1^2$$

$$\Rightarrow \quad V_1 = 2.215 \text{ m/s}$$

8. (d)

As, $\quad$ Drag force, $F = \rho V^2 L^2$

$$\frac{F_m}{F_p} = \frac{\rho_m V_m^2 L_m^2}{\rho_p V_p^2 L_p^2} \qquad \text{... (i)}$$

As, $\quad \text{Re}_m = \text{Re}_p$

$$\frac{\rho_m V_m L_m}{\mu_m} = \frac{\rho_p V_p L_p}{\mu_p}$$

$$\frac{V_m}{V_p} = \frac{L_p}{L_m} \qquad \text{... (ii)}$$

Using equation (i) and (ii)

$$\frac{F_m}{F_p} = 1$$

$$\Rightarrow \quad F_p = 300 \text{ N}$$

9. (a)

$$\tau = \mu\frac{du}{dx} = \mu(4-4x)$$

$$= 2(4 - 4 \times 1) = 0 \text{ N/m}^2$$

10. (c)

Applying mass conservation.

$$A_1V_1 = A_2V_2 + A_3V_3$$

$$\Rightarrow \quad 450^2 \times 4 = 300^2 \times 3 + 250^2 \times V_3$$

$$V_3 = 8.64 \text{ m/s}$$

11. (a)

Applying Bernoulli's equation between the two reservoirs, we get

$$12.5 = 0.5\frac{V^2}{2g} + \frac{fLV^2}{2gD} + \frac{V^2}{2g}$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{2g}\left[1.5 + \frac{fL}{D}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{2 \times 10}\left[1.5 + \frac{0.04 \times 1000}{0.5}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{20} \times 81.5$$

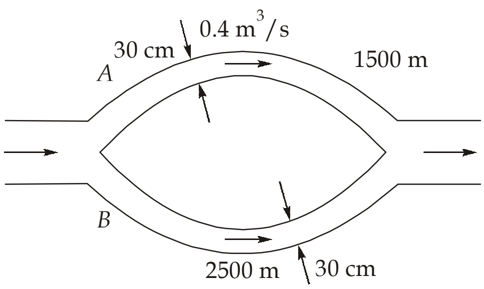
$$\Rightarrow \quad V = 1.75 \text{ m/s}$$

12. (b)

The average velocity in pipe A,

$$V_A = \frac{\dot{V}}{A_c} = \frac{\dot{V}}{\pi D^2/4} = \frac{0.4 \text{ m}^3\text{/s}}{\pi(0.30 \text{ m})^2/4} = 5.659 \text{ m/s}$$

When two pipes are parallel in a piping system, that head loss for each pipe must be same. When the minor losses are disgarded, the head loss for fully developed flow in a pipe of length L and diameter D is



$$h_L = f\frac{L}{D}\frac{V^2}{2g}$$

In case of parallel pipe fluid flow problem

Head losses are same,

$$(h_L)_A = (h_L)_B$$

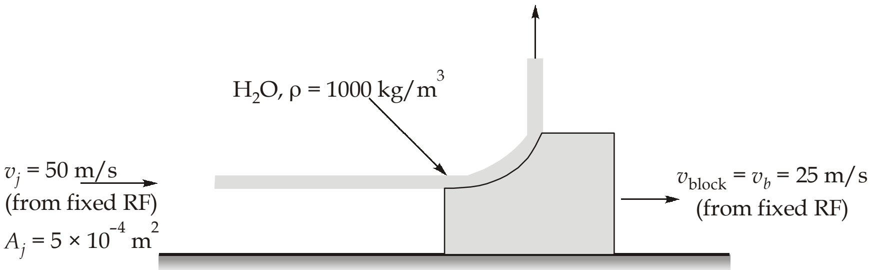
$$f_A \frac{L_A}{D_A}\frac{V_A^2}{2g} = f_B \frac{L_B}{D_B}\frac{V_B^2}{2g}$$

$$V_B = V_A\sqrt{\frac{L_A}{L_B}} = (5.659 \text{ m/s})\sqrt{\frac{1500\text{m}}{2500\text{m}}} = 4.383 \text{ m/s}$$

Then the flow rate in pipe B becomes

$$\dot{V}_B = A_B V_B = \left[\frac{\pi D^2}{4}\right]V_B = \left[\frac{\pi(0.3\text{m})^2}{4}\right](4.383\text{m/s}) = 0.310 \text{ m}^3\text{/s}$$

13. (c)



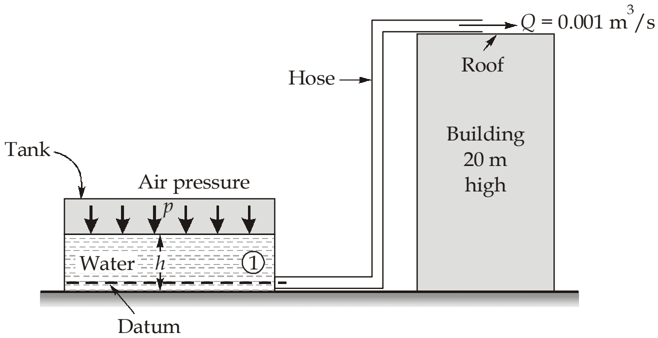
Frictional force on block = Change of momentum of block

$$F_f = \rho A_j (v_j - v_b)^2$$

$$= (1000)(5 \times 10^{-4})(50 - 25)^2$$

$$F_f = 312.5 \text{ N}$$

14. (c)



Let 'p' be the air pressure inside the tank.

The velocity of water in the hose,

$$V = \frac{Q}{A} = \frac{0.001}{\frac{\pi}{4}\times(0.05)^2} = 0.509 \text{ m/s}$$

Applying the Bernoulli's equation to the inlet end (1) and the output end of the hose at 20 m height above the bottom level, (Assuming the horizontal line passing through (1) as the datum).

$$\frac{p}{\gamma} + h = 20 + \frac{V^2}{2g} + 0.06$$

where, p is the pressure of air in the tank, h is the water depth.

Now, $h << 20$ m (given)

$$\frac{p}{\gamma} = 20 + \frac{(0.509)^2}{2 \times 9.81} + 0.06 = 20.073 \text{ m of water}$$

15. (c)

As per given data: $Q = 2.5\ l/s = 2.5 \times 10^{-3}\ \text{m}^3/\text{s}$

$D = 45$ mm, $d = 25$ mm

$\rho = 1000$ kg/m^3

From continuity, $$V_1 = \frac{Q}{\left(\frac{\pi D^2}{4}\right)} = 1.57 \text{ m/s}$$

$$V_2 = \frac{Q}{\left(\frac{\pi d^2}{4}\right)} = 5.09 \text{ m/s}$$

Hence, applying Bernoulli between (1) and (2)

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} = \frac{p_2}{\rho} + \frac{V_2^2}{2}$$

or, in gauge pressure, $$p_{1g} = \frac{\rho}{2}\left(V_2^2 - V_1^2\right) = \left(\frac{1000}{2}\right) \times (5.09^2 - 1.57^2) = 11.721 \text{ kPa}$$

16. (d)

$$\rho_{water} = 1000 \text{ kg/m}^3.$$

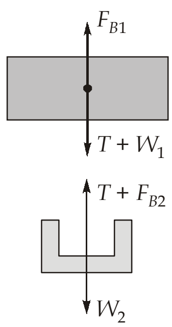
Apply the hydrostatic relation from the oil surface to the water surface, skipping the 8 cm part:

$p_{atm} + (898)(9.81)(h + 0.12) - (1000)(9.81)(0.06 + 0.12) = p_{atm}$

On solving, $h = 0.08$ m

17. (d)

As the given data: Free body diagram



From ΣF_y

$$T = F_{B1} - W_1$$

$$F_{B1} = \rho g(\text{V})_{submerged}$$

$$= (9.8 \times 1000)(50 \times 50 \times 7.5)(10^{-9})$$

$$F_{B1} = 0.18375 \text{ N}$$

$$W_1 = \gamma(\text{Specific gravity of block}) \times \text{Volume of block}$$

$$= (9.8 \times 1000)(0.3)(50 \times 50 \times 10)(10^{-9}) = 0.0735 \text{ N}$$

$$T = (0.18375 - 0.0735) = 0.11025 \text{ N}$$

3. Force equilibrium (vertical direction) applied to metal part:

$$F_{B2} = \gamma V_2 = (9800)(6600)(10^{-9})$$

$$= 0.06468 \text{ N}$$

$$W_2 = T + F_{B2} = (0.1102 \text{ N}) + (0.06468 \text{ N})$$

Mass of metal part, $m_2 = \dfrac{W_2}{g} = 0.01785 \text{ kg}$

18. (b)

The frontal area of a sphere is $A = \dfrac{\pi D^2}{4}$.

The drag force acting on the balloon is

$$F_D = C_D A \frac{\rho V^2}{2} = (0.2)\left[\frac{\pi(7)^2}{4}\right]\frac{(1.20)\left(\frac{40\times 5}{18}\right)^2}{2} = 570.14 \text{ N}$$

Acceleration in the direction of the winds

$$a = \frac{F_D}{m} = \frac{570.14}{350} = 1.63 \text{ m/s}^2$$

19. (a)

Pressure gradient $\left(\dfrac{\partial p}{\partial x}\right)$,

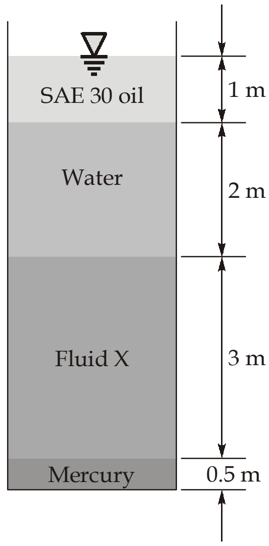
$$\therefore \quad U_{max} = \frac{-1}{8\mu}\left(\frac{\partial p}{\partial x}\right) \times t^2$$

$$\Rightarrow \quad 3 = \frac{-1}{8 \times 0.02}\left(\frac{\partial p}{\partial x}\right) \times (0.015)^2$$

$$\Rightarrow \quad \left(\frac{\partial p}{\partial x}\right) = \frac{-3 \times 8 \times 0.02}{(0.015)^2} = -2133.33 \text{ N/m}^2\text{/m}$$

20. (b)

Simply apply the hydrostatic formula from top to bottom:



$$p_{bottom} = p_{top} + \Sigma wh,$$

$$323.33 \times 10^3 = 101330 + 0.872 \times 10^3 \times 10 \times 1 + 10^3 \times 10 \times 2 + (SG)_x \times 10^3 \times 10 \times 3 + 13.6 \times 10^3 \times 10 \times 0.5$$

or, $$SG_X = 4.176$$

21. (d)

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

as $$u = (U_o + bx)$$

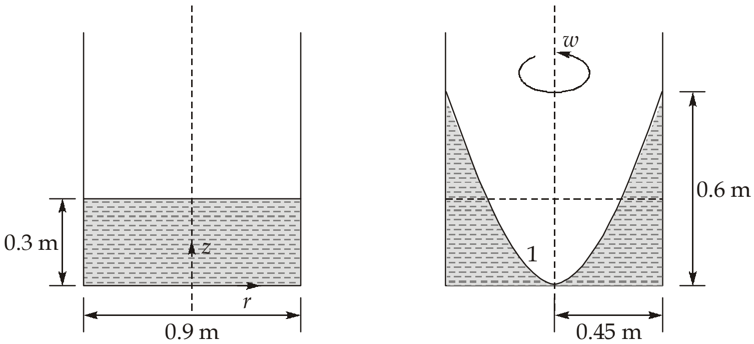
$$v = -by$$

$$\frac{\partial v}{\partial x} = 0 \qquad \frac{\partial u}{\partial y} = 0$$

So, $$\omega_z = 0$$

Hence, flow is steady and irrotational.

22. (a)



Initial conditions

Final condition when bottom starts exposing

Apply forced vortex motion equation at points (1) and (2)

$$\frac{P_1}{\rho g} - \frac{(V_1)^2}{2g} + z_1 = \frac{P_2}{\rho g} - \frac{(V_2)^2}{2g} + z_2$$

At point 1, $P_1 = P_{atm} \Rightarrow P_{gauge} = 0$

$V_1 = \omega R_1 = 0$

$z_1 = 0$

At point, $P_2 = P_{atm} \Rightarrow P_{gauge} = 0$

$z_2 = 0.6$

Therefore, $$0 - 0 + 0 = 0 - \frac{(\omega R_2)^2}{2g} + 0.6$$

$$\Rightarrow \quad \frac{\omega^2 (0.45)^2}{2 \times (9.81)} = 0.6$$

$$\Rightarrow \quad \omega = 7.624 \text{ rad/s}$$

23. (b)

$D_i = 6 \times 10^{-2}$ m

$D_f = 6.9 \times 10^{-2}$ m

As soap bubble has two surfaces,

Therefore total change in surface area $= 2\left[4\pi\left(R_f^2 - R_i^2\right)\right] = 2\left[\pi\left(D_f^2 - D_i^2\right)\right]$

$= 2\,(0.003647) = 7.294 \times 10^{-3}$ m^2

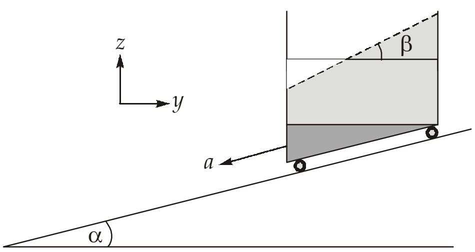
Work input required, $W = \sigma \times \Delta A = 0.039 \times 7.294 \times 10^{-3}$

$= 2.845 \times 10^{-4}$ Joule

24. (c)

As per given information. It needs to be determined, relation between the slope of the liquid surface and the slope of the inclined surface when the tank is released.

$$\tan\beta = -\frac{a_y}{g + a_z} = \frac{-a\cos\alpha}{g - a\sin\alpha}$$



Since, $a = g\sin\alpha$,

we get, $$\tan\beta = \frac{g\sin\alpha\cos\alpha}{g - g\sin\alpha\sin\alpha} = \frac{\sin\alpha\cos\alpha}{1 - \sin^2\alpha}$$

$$= \frac{\sin\alpha\cos\alpha}{\cos^2\alpha} = \tan\alpha$$

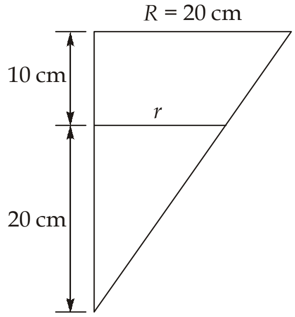
Therefore, $\alpha = \beta$

25. (b)

Assumption: The buoyancy force in air is negligible,

$$\rho_{water} = 1000 \text{ kg/m}^3, \qquad h = 0.2 \text{ m}$$

From geometry



$$\frac{R}{30} = \frac{r}{20}$$

and $$r = \frac{2R}{3} = \frac{40}{3} = 13.33 \text{ cm}$$

The displaced volume of water is

$$\forall = \frac{1}{3}\pi r^2 h = \frac{1}{3}\times\pi\times 0.1333^2\times 0.2$$

$$= 3.72 \times 10^{-3} \text{ m}^3$$

Therefore, the buoyancy force acting on the cone is

$$F_b = \rho g \forall = 9810\times 3.72\times 10^{-3} = 36.49 \text{ N}$$

For the static equilibrium,

$$F + W_c = F_b$$

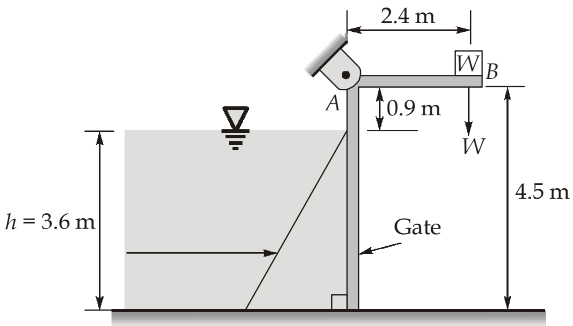
$$F + 16.5 = 36.5$$

$$F = 20 \text{ N}$$

26. (a)

As per given information,

1.5 m wide, $\rho_{water} = 1000 \text{ kg/m}^3$



The resultant hydrostatic force acting on the dam becomes,

$$F_R = \rho g \bar{x} A = 1000\times 9.81\times\frac{3.6}{2}\times 3.6\times 1.5 \text{ N} = 95353.2 \text{ N}$$

The line of action of the force passes through the pressure centre which is $\frac{2h}{3}$ from the free surface.

$$\bar{h} = \frac{2h}{3} = \frac{2\times 3.6}{3} = 2.4 \text{ m}$$

Taking the moment about point A and setting it equal to zero gives,

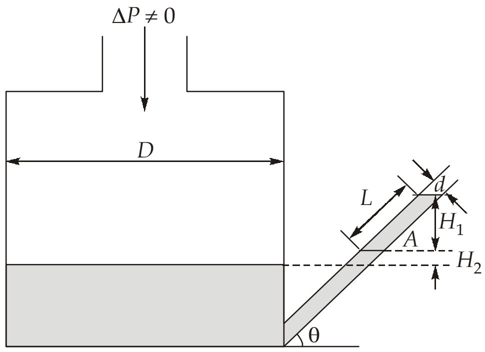
$$\Sigma M_A = 0$$

$$F_R\left(0.9 + \bar{h}\right) = W \times 2.4$$

$$W = 131110.65$$

$$\text{Mass} = \frac{W}{9.81} = \frac{131110.65}{9.81} = 13365\text{ kg} = 13.36 \times 10^3\text{ kg}$$

27. (c)



Volume rise in tube = Volume fall in reservoir

$$\Rightarrow \quad \frac{\pi}{4}d^2 \times L = \frac{\pi}{4}D^2 \times H_2$$

$$\Rightarrow \quad H_2 = L\left(\frac{d}{D}\right)^2$$

Also, $H_1 = L\sin\theta$

$$\Rightarrow \quad \Delta P = \rho g(H_1 + H_2) = \rho g\left[L\left(\frac{d}{D}\right)^2 + L\sin\theta\right]$$

$$\Rightarrow \quad L = \frac{\Delta P}{\rho g\left(\sin\theta + \frac{d^2}{D^2}\right)}$$

28. (d)

$$\text{Wall shear stress, } \tau_o = -\frac{\partial P}{\partial x} \times \frac{R}{2}$$

$$-\frac{\partial P}{\partial x} = -\frac{P_2 - P_1}{x_2 - x_1} = \frac{P_1 - P_2}{L} = \frac{\Delta P}{L} = \frac{1800 \times 10^3}{100} = 18000$$

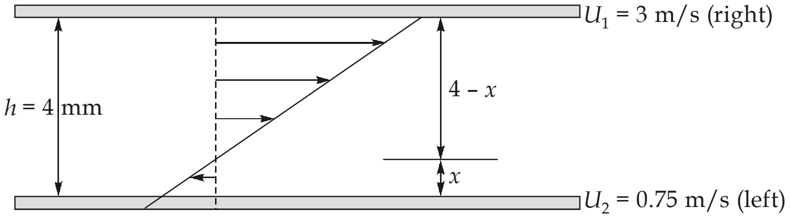
$$\tau_o = 18000 \times \frac{0.06}{4} = 270\text{ N/m}^2$$

Frictional drag for 100 m length,

$$F_D = \tau_o \times \pi DL = 270 \times \pi \times 0.06 \times 100$$

$$= 5089\text{ N or } 5.089\text{ kN}$$

29. (d)



From similar triangle ΔABC and ΔCDE

$$\frac{4-x}{x} = \frac{3}{0.75}$$

$$3x = (4-x)(0.75)$$

$$3x = 3 - 0.75x$$

$$x = 0.8 \text{ mm}$$

$$y = 4 - x = 3.2 \text{ mm}$$

$$\dot{V}_{net} = (3.2\times10^{-3})(5\times10^{-2})\frac{3}{2} - (0.8\times10^{-3})(5\times10^{-2})\frac{0.75}{2}$$

$$\dot{V}_{net} = 24 \times 10^{-5} - 1.5 \times 10^{-5} = 225 \times 10^{-6} \text{ m}^3/\text{s} = 225 \text{ cm}^3/\text{s}$$

30. (c)

As per given data:

$$u^* = \frac{u}{U} \text{ and } y^* = \frac{y}{\delta}$$

$$dy^* = \delta^{-1}\, dy$$

The given parabolic velocity distribution and the expression for the displacement thickness can then be expressed as

$$u^* = 2y^* - y^{*2}, \text{ and } \delta^* = \delta\int_0^1 (1-u^*)\,dy^*$$

Combining these equations gives,

$$\delta^* = \delta\int_0^1 (1-2y^* + y^{*2})\,dy^*$$

$$\delta^* = \delta\left[y^* - y^{*2} + \frac{1}{3}y^{*3}\right]_0^1$$

$$\delta^* = \frac{1}{3}\delta$$

$$\frac{\delta^*}{\delta} = \frac{1}{3}$$

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