Essential Equations for the Mechanical PE Exam Using the HP 33s

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STORING EQUATIONS

A

FLUIDS

Equation 1: Pressure on a Submerged Inclined Rectangular Plane Surface

$$h_R = \left(\frac{\frac{2}{3}}{\sin\theta}\right)\left(h_1 + h_2 - \frac{h_1 h_2}{h_1 + h_2}\right)$$

Entered as

`R=((2÷3)÷SIN(T))×(H+G-(H×G÷(H+G)))`

Sessions AM, PM

Discipline Thermal and Fluids Systems

Variables

$G = h_2$	bottom height	ft	m
$H = h_1$	top height	ft	m
$R = h_R$	resultant height	ft	m
$T = \theta$	angle between inclined plane and horizontal	deg	deg

Keys	Display	Description
[↱] [EQN] [RCL] [R] [↱] [=]	`R=▮`	Selects Equation mode and starts new equation. *R* is resultant height (h_R).
[↱] [(] [↱] [(] [2]	`R=(( 2_`	Cursor changes for entering digits.
[÷] [3] [↱] [)]	`R=((2÷3)▮`	
[÷] [SIN]	`R=((2÷3)÷SIN(▮`	Opens sine function.

[RCL] [T] [↱] [)] [↱] [)]	`(2÷3)÷SIN(T))▮`	Closes sine function. *T* is angle between inclined plane and horizontal (θ). Equation is now longer than the hp 33s display. For instructions on scrolling left and right, see How to Use This Book.
[×] [↱] [(] [RCL] [H] [+] [RCL] [G]	`÷SIN(T))×(H+G▮`	*H* is top height (h_1) and *G* is bottom height (h_2).
[−] [↱] [(] [RCL] [H] [×] [RCL] [G]	`T))×(H+G-(H×G▮`	
[÷] [↱] [(] [RCL] [H] [+] [RCL] [G]	`H+G-(H×G÷(H+G▮`	
[↱] [)] [↱] [)] [↱] [)]	`-(H×G÷(H+G)))▮`	
[ENTER]	`R=((2÷3)÷SIN(T`	Ends equation.
[↱] [SHOW]	`CK=91FA` `LN=34`	Hold down SHOW to display checksum and length of equation. If numbers displayed match these, equation is correctly entered.

Equation 2: Energy Equation (Bernoulli equation, U.S. units)

$$\frac{p_1}{\gamma} + \frac{\mathrm{v}_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{\mathrm{v}_2^2}{2g} + z_2 + h_f$$

Entered as

`144×P÷G+SQ(V)÷64.4+Z=144×O÷G+SQ(U)÷64.4+Y+H`

Sessions AM, PM

Disciplines HVAC, Thermal and Fluids Systems

Variables

$G = \gamma$	specific weight	lbf/ft^3
$H = h_f$	head loss due to friction	ft
$O = p_2$	pressure at point 2	lbf/in^2
$P = p_1$	pressure at point 1	lbf/in^2
$U = \mathrm{v}_2$	velocity at point 2	ft/sec
$V = \mathrm{v}_1$	velocity at point 1	ft/sec
$Y = z_2$	elevation at point 2	ft
$Z = z_1$	elevation at point 1	ft

Notes This equation can be used to solve problems with or without head loss. If there are no friction losses to take into account, enter zero as the value for H. For problems in real fluid flow or steady, incompressible flow in conduits and pipes, H stands for h_f.

For consistent units in this equation, pressure must be in pounds per square foot, but pressure is usually given in pounds per square inch. For this reason, both p_1 and p_2 are multiplied by 144 in the stored equation. When using this equation to solve a problem, enter pressure in pounds per square inch and the values will be converted automatically.

Keys	Display	Description
[↱] [EQN] [1] [4] [4]	`144_`	Selects Equation mode and starts new equation. Pressure is multiplied by 144 to convert from psi to psf. Cursor changes for entering digits.
[×] [RCL] [P]	`144×P■`	P is pressure at point 1 (p_1).
[÷] [RCL] [G]	`144×P÷G■`	G is specific weight (γ).
[+] [x^2]	`144×P÷G+SQ(■`	Opens square function.
[RCL] [V] [↱] [)]	`144×P÷G+SQ(V)■`	V is velocity at point 1 (v_2). Closes square function.

÷ 6 4 . 4	÷G+SQ(V)÷ 64.4_	Cursor changes for entering digits. *g* is gravitational acceleration, 32.2 ft/sec^2. 64.4 is the value of 2*g*. Equation is now longer than the hp 33s display. For instructions on scrolling left and right, see How to Use This Book.
+ RCL Z	G+SQ(V)÷64.4+Z▮	*Z* is elevation at point 1 (z_1).
↱ = 1 4 4	V)÷64.4+Z= 144_	
× RCL O	)÷64.4+Z=144×O▮	*O* is pressure at point 2 (p_2).
÷ RCL G + x^2 RCL U	144×O÷G+SQ(U▮	*U* is velocity at point 2 (v_2).
↱) ÷ 6 4 . 4	÷G+SQ(U)÷ 64.4_	
+ RCL Y + RCL H	SQ(U)÷64.4+Y+H▮	*Y* is elevation at point 2 (z_2). *H* is head loss due to friction (h_f).
ENTER	P÷G+SQ(V)÷64.4+	Ends equation.
↱ SHOW	CK=329D LN=43	Hold down SHOW to display checksum and length of equation. If numbers displayed match these, equation is correctly entered.

Equation 3: Reynolds Number

$$\text{Re} = \frac{d\text{v}}{\nu}$$

Entered as

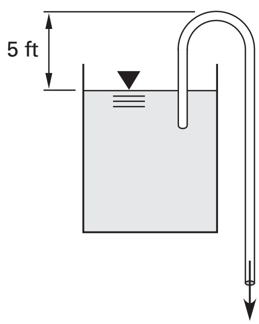
R=D×V÷N

PRACTICE PROBLEMS USING STORED EQUATIONS

B

PROBLEM 1

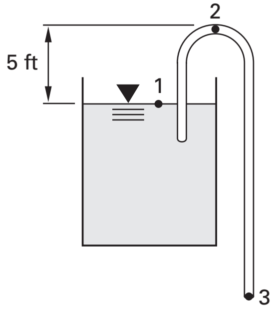
Water is being drawn through a siphon from a tank as shown. The temperature of the tank is 70°, and the specific weight of water at this temperature is 62.3 lbf/ft^3. There is no head loss. At the surface of the water, the velocity is zero and the atmospheric pressure is 14.7 psia. The velocity of the water at the lower end of the siphon is 30 ft/sec.



The pressure in the siphon at its highest point is most nearly

(A) 0.44 psia
(B) 6.5 psia
(C) 8.7 psia
(D) 13 psia

SOLUTION 1



Head loss is negligible, so h_f is zero. From the law of conservation of mass for an incompressible fluid, the velocity at point 2 is the same as the velocity at point 3. Take point 1 as the zero height reference. Use the formula for Bernoulli's equation (Equation 2, p. 10).

Keys	Display	Description
[↱] [EQN]	144×P÷R+SQ(V)÷	Enters Equation mode. Scroll through list to bring needed equation to bottom line of display.
[SOLVE] [O]	P? 0.0000	Starts to solve for *O*. Prompts for *P* and displays current value.
[1] [4] [.] [7] [R/S]	G? 0.0000	Enters 14.7 for *P*. Prompts for *G* and displays current value.
[6] [2] [.] [3] [R/S]	V? 0.0000	Enters 62.3 for *G*. Prompts for *V* and displays current value.
[0] [R/S]	Z? 0.0000	Enters zero for *V*. Prompts for *Z* and displays current value.
[0] [R/S]	U? 0.0000	Enters zero for *Z*. Prompts for *U* and displays current value.
[3] [0] [R/S]	Y? 0.0000	Enters 30 for *U*. Prompts for *Y* and displays current value.

[5] [R/S]	H? 0.0000	Enters 5 for *Y*. Prompts for *H* and displays current value.
[0] [R/S]	O= 6.4906	Enters zero for *H* and solves for *O*.

The answer is (B).

PROBLEM 2

A 24 in diameter pipeline carries sweet crude oil (specific gravity 0.86, kinematic viscosity 4×10^{-5} ft^2/sec) to a refinery at a rate of 14,000 gal/min. The flow inside the pipe is most nearly

(A) laminar, Re = 2.0×10^3
(B) turbulent, Re = 8.5×10^3
(C) turbulent, Re = 41×10^3
(D) turbulent, Re = 500×10^3

SOLUTION 2

The size of the Reynolds number determines whether the flow is laminar or turbulent.

The average of the velocity of the flow inside the pipe is found from the formula

$$Q = \mathrm{v}A$$

$$\mathrm{v} = \frac{Q}{A} = \frac{\left(14{,}000\ \frac{\text{gal}}{\text{min}}\right)\left(\frac{1\ \text{ft}^3}{7.48\ \text{gal}}\right)\left(\frac{1\ \text{min}}{60\ \text{sec}}\right)}{\left(\frac{\pi}{4}\right)(24\ \text{in})^2\left(\frac{1\ \text{ft}}{12\ \text{in}}\right)}$$

$$= 9.9\ \text{ft/sec}$$

Use the formula for the Reynolds number (Equation 3, p. 12).

Keys	Display	Description
[⮫] [EQN]	R=D×V÷N	Enters Equation mode. Scroll through list to bring needed equation to bottom line of display.
[ENTER]	D? 0.0000	Starts to solve for *R*. Prompts for *D* and displays current value.