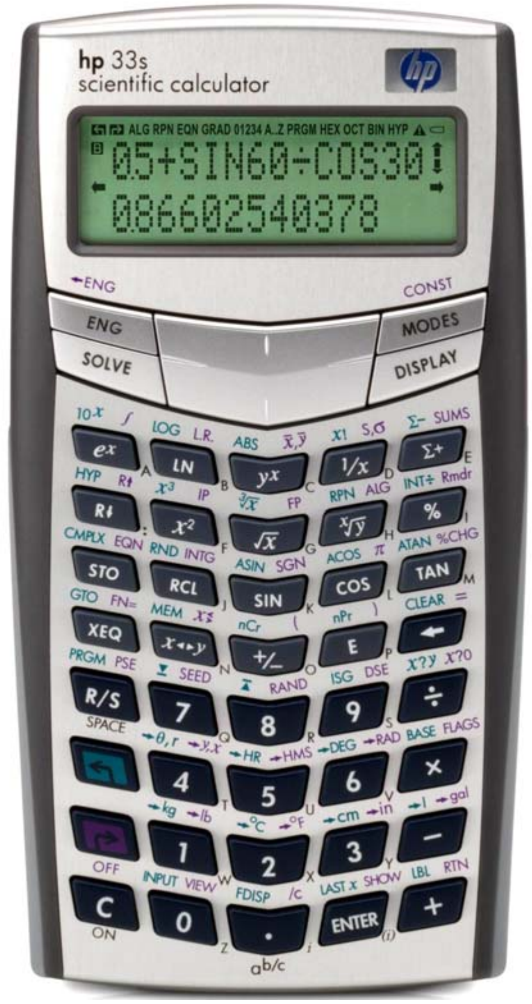
hp calculators




HP 33S Applications in mechanical engineering

Applications in mechanical engineering

Practice solving problems in mechanical engineering

- Application 1: Stress on an element (Mohr circle)
- Application 2: Gear forces (worm gears)

## Applications in mechanical engineering

This training aid will illustrate the application of the HP 33S calculator to several problems arising in mechanical engineering. These examples are far from exhaustive, but do indicate the incredible flexibility of the HP 33S calculator.

## Practice solving problems in mechanical engineering

### Application 1: Stress on an element (Mohr circle)

The Mohr circle equations convert an arbitrary stress configuration to principal stresses, maximum shear stress, and rotation angle. It is then possible to calculate the state of stress for an arbitrary orientation θ'.

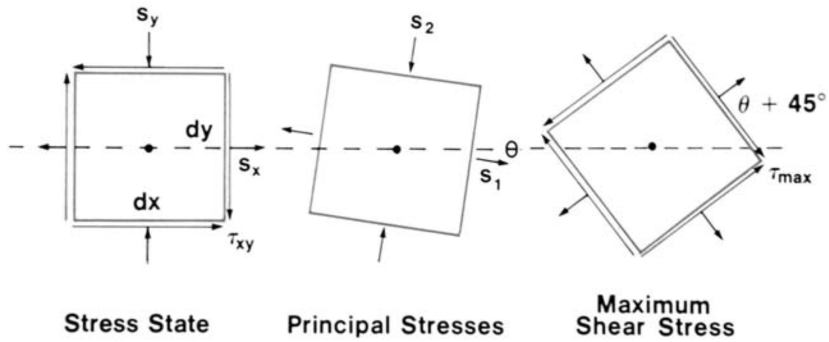



Figure 1

The Mohr circle formulas are shown below, where s is the normal stress, τ is the shear stress, $s_x$ is the stress in the x direction for Mohr circle input, $s_y$ is the stress in the y direction for Mohr circle input, $\tau_{xy}$ is the shear stress on the element for the Mohr circle input, $s_1$ and $s_2$ are the principal stresses, θ is the rotation angle, and $\tau_{max}$ is the maximum shear stress. Note that θ is the angle of rotation from the specified axis to the principal axis, and so should be thought of as a negative angle. This is opposite to the normal Mohr circle convention.

Maximum shear stress $$\tau_{max} = \sqrt{\left(\frac{s_x - s_y}{2}\right)^2 + \tau_{xy}^2}$$ Figure 2

Principal stress $$s_1 = \frac{s_x + s_y}{2} + \tau_{max}$$ Figure 3

Principal stress $$s_2 = \frac{s_x + s_y}{2} - \tau_{max}$$ Figure 4

Rotation angle $$\theta = \frac{1}{2}\tan^{-1}\left(\frac{2\tau_{xy}}{s_x - s_y}\right)$$ Figure 5

Example: If $s_x$ = 25,000 psi, $s_y$ = -5,000 psi, and $\tau_{xy}$ = 4,000 psi, compute the principal stresses, the angle of rotation $\theta$, and the maximum shear stress.

Solution: Solve for the maximum shear stress, $\tau_{max}$.

In RPN mode: 2 5 0 0 0 ENTER 5 0 0 0 +/- − 2 ÷ $x^2$ 4 0 0 0 $x^2$ + $\sqrt{x}$ STO T

In algebraic mode: 2 5 0 0 0 − 5 0 0 0 +/- ENTER ÷ 2 ENTER $x^2$ + 4 0 0 0 $x^2$ ENTER $\sqrt{x}$ STO T

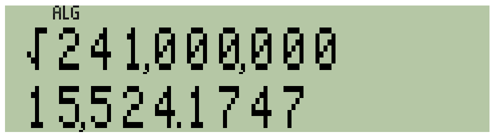


Figure 6

Solve for the principal stress, $s_1$.

In RPN mode: 2 5 0 0 0 ENTER 5 0 0 0 +/- + 2 ÷ RCL T +

In algebraic mode: 2 5 0 0 0 + 5 0 0 0 +/- ENTER ÷ 2 + RCL T ENTER

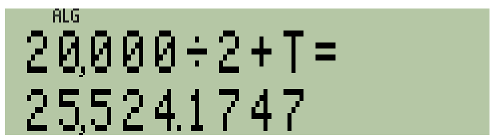


Figure 7

Solve for the principal stress, $s_2$.

In RPN mode: 2 5 0 0 0 ENTER 5 0 0 0 +/- + 2 ÷ RCL T −

In algebraic mode: 2 5 0 0 0 + 5 0 0 0 +/- ENTER ÷ 2 − RCL T ENTER

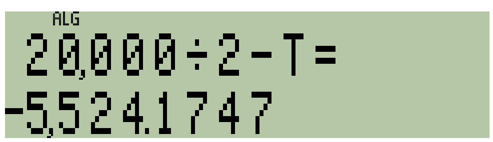


Figure 8

Solve for the rotation angle, $\theta$.

In RPN mode: 2 ENTER 4 0 0 0 × 2 5 0 0 0 ENTER 5 0 0 0 +/- − ÷ ↰ ATAN 2 ÷

In algebraic mode: 2 × 4 0 0 0 ÷ ↱ ( 2 5 0 0 0 − 5 0 0 0 +/- ↱ ) ENTER ↰ ATAN ÷ 2 ENTER

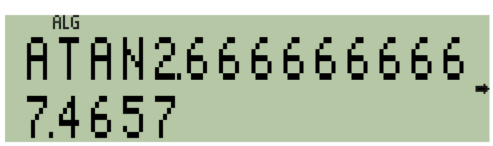


Figure 9

Answer: The principal stresses, $s_1$ and $s_2$, are 25,524 psi and -5,524 psi. The angle of rotation, $\theta$, is 7.4657 degrees. The maximum shear stress is 15,524 psi.

## Application 2: Gear forces (worm gears)

There are three mutually perpendicular forces resulting from input torque on worm gears as shown below.

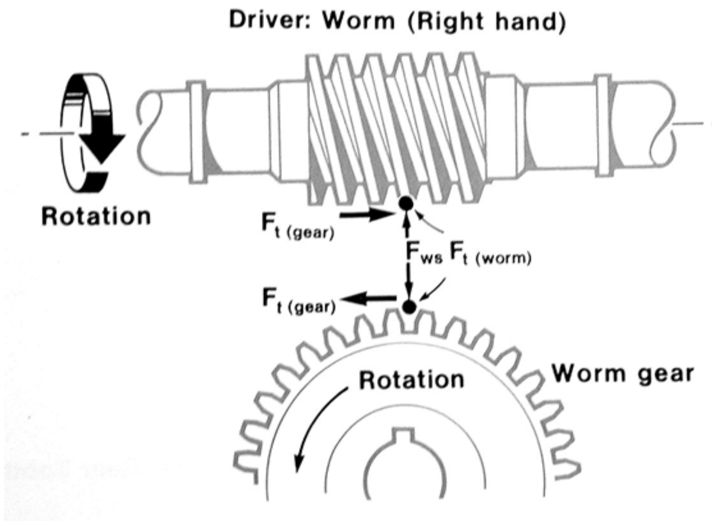



Figure 10

The worm gear force formulas are shown below, where T is the input (worm) torque, n is the pitch radius of the worm, $F_t$ is the tangential force on the worm, $\alpha$ is the lead angle of the worm, L is the lead of the worm, r is the pitch radius of the worm gear, $\phi_n$ is the pressure angle measured perpendicular to the worm teeth, $\phi$ is the pressure angle measured parallel to the worm axis, f is the coefficient of friction, $F_{ws}$ is the separating force between the worm and the gear, and $F_{gax}$ is the force parallel to the gear axis.

Tangential force

$$F_t = \frac{T}{r}$$

Figure 11

Separating force - worm and gear

$$F_{ws} = F_t\left(\frac{\sin\phi_n}{\cos\phi_n \sin\alpha + f\ \cos\alpha}\right)$$

Figure 12

Force parallel to gear axis

$$F_{gax} = F_t\left(\frac{1 - \dfrac{f\ \tan\alpha}{\cos\phi_n}}{\tan\alpha + \dfrac{f}{\cos\phi_n}}\right)$$

Figure 13

Lead angle

$$\alpha = \tan^{-1}\left(\frac{L}{2\pi r}\right)$$

Figure 14

Pressure angle parallel to worm gear

$$\phi = \tan^{-1}\left(\frac{\tan\phi_n}{\cos\alpha}\right)$$

Figure 15

<u>Example:</u> A torque of 512 in-lb is applied to a worm gear having a pitch diameter of 2.92 inches and a lead of 2.2. inches. The normal pressure angle is 20 degrees and the coefficient of friction is 0.10. Find the lead angle, the forces on the worm and worm gear, and the tangential force.

<u>Solution:</u> Solve for tangential force and store it in variable F.

In RPN mode: [5] [1] [2] [ENTER] [2] [·] [9] [2] [ENTER] [2] [÷] [÷] [STO] [F]

In algebraic mode: [5] [1] [2] [÷] [↱] [(] [2] [·] [9] [2] [÷] [2] [↱] [)] [ENTER] [STO] [F]

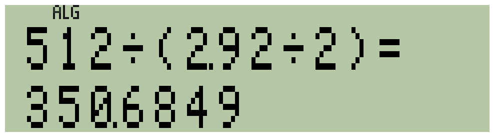



Figure 16

Solve for the lead angle and store it in variable A. Make sure the HP 33S is in degrees mode first.

In RPN mode: [MODES] [1]
[2] [·] [2] [ENTER] [2] [÷] [↱] [π] [÷] [2] [·] [9] [2] [ENTER] [÷] [2] [÷]
[↰] [ATAN] [STO] [A]

In algebraic mode: [MODES] [1]
[2] [·] [2] [÷] [2] [÷] [↱] [π] [÷]
[↱] [(] [2] [·] [9] [2] [÷] [2] [↱] [)] [ENTER] [↰] [ATAN] [STO] [A]

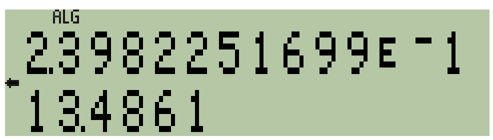



Figure 17

Solve for the separating force on the worm.

In RPN mode: [RCL] [A] [SIN] [↰] [LAST$x$] [COS] [0] [·] [1] [×] [$x$↔$y$] [2] [0] [COS] [×] [+]
[2] [0] [SIN] [$x$↔$y$] [÷] [RCL] [F] [×]

In algebraic mode: [2] [0] [SIN] [÷] [↱] [(] [2] [0] [COS] [×] [RCL] [A] [SIN] [+]
[0] [·] [1] [×] [RCL] [A] [COS] [↱] [)] [×] [RCL] [F] [ENTER]

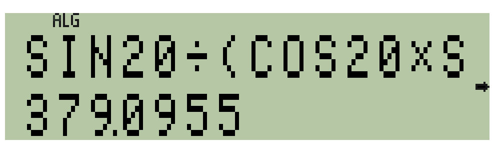



Figure 18

Solve for the force parallel to the gear axis.

In RPN mode: [RCL] [A] [TAN] [0] [·] [1] [×] [2] [0] [COS] [÷] [1] [$x$↔$y$] [−]
[0] [·] [1] [ENTER] [2] [0] [COS] [÷] [RCL] [A] [TAN] [+] [÷]
[RCL] [F] [×]

In algebraic mode: [RCL] [F] [×] [↱] [(] [↱] [(] [1] [−] [0] [·] [1] [×] [RCL] [A] [TAN] [÷]
[2] [0] [COS] [↱] [)] [÷] [↱] [(] [RCL] [A] [TAN] [+] [0] [·] [1] [÷]
[2] [0] [COS] [↱] [)] [↱] [)] [ENTER]

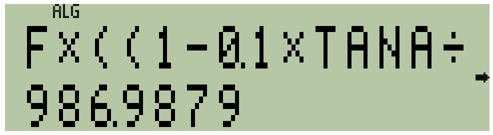



Figure 19

Answer: The lead angle is 13.49 degrees, the separating force on the worm is approximately 379 pounds and the force parallel to the worm gear axis is approximately 987 pounds. The tangential force is approximately 351 pounds.