

Six-Minute Solutions

**for Mechanical PE Exam
Mechanical Systems
and Materials Problems**

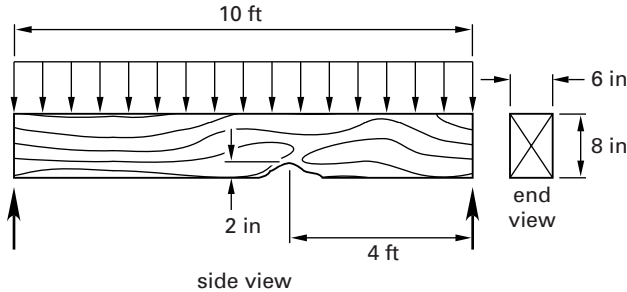
Second Edition

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PROBLEM 41

A simply supported 6 in by 8 in wood beam spanning 10 ft is supporting a distributed load. The beam is damaged 4 ft from the end, causing 2 in of material to be removed.



not to scale

If the allowable stress is 1200 psi, the reduction in the distributed load at the damage is most nearly

- (A) 25%
- (B) 33%
- (C) 43%
- (D) 56%

Hint: Use moment and shear calculations to determine the distributed load at the center of the span and at the damaged section.

PROBLEM 42

An old wooden platform cantilevers over an extruder supporting a plastic compound hopper. The deck is supported by 2 in x 12 in joists 16 in on center extending 80 in. The flooring is 3/4 in thick. The maximum weight of the plastic compound hopper and storage boxes distributes 500 lbf over each joist. The extruder operators are concerned for their safety while working under the old platform and want to make sure it is not overloaded. Using 35 lbf/ft³ for the specific weight of the wood, the allowable stress on each joist is most nearly

- (A) 120 psi
- (B) 630 psi
- (C) 690 psi
- (D) 1300 psi

Hint: Determine the effect of each component of the platform and the weight of the plastic on a single joist. Remember that the actual dimensions of wooden members differ from their nominal dimensions.

APPLICATIONS: MECHANICAL COMPONENTS

PROBLEM 43

What class of fit would be specified to achieve a constant pressure on a bearing?

- (A) running and sliding fit
- (B) locational fit
- (C) force fit
- (D) accurate fit

Hint: Classes of fits are arranged in three general groups.

PROBLEM 44

A machine twists a pair of copper wires at 5 rev/ft and runs at a speed of 300 ft/min. The twisted pair is wound by a mechanism supported by a deep-groove ball bearing. The bearing has a catalog-rated life of 3000 hr and a catalog-rated speed of 500 rpm. The load rating for the bearing and the application are the same. In machine hours, the bearing should be replaced every

- (A) 15 hr
- (B) 360 hr
- (C) 1000 hr
- (D) 3000 hr

Hint: Use the speed of the winding mechanism and the total number of bearing revolutions to determine the number of machine hours for each recommended service interval.

PROBLEM 45

A tapered roller bearing with a contact angle of 20° experiences combined thrust and radial forces as shown in the table. The inner race rotates, and shock and impact are negligible.

load phase	phase description	speed (rpm)	time (sec)	thrust force (lbf)	radial force (lbf)	thrust factor X	radial factor Y
1	load/advance	500	7	500	250	0.4	0.4 cot α
2	spin	5000	10	1000	750	0.4	0.4 cot α
3	retract/unload	250	3	-250	500	0.4	0.4 cot α

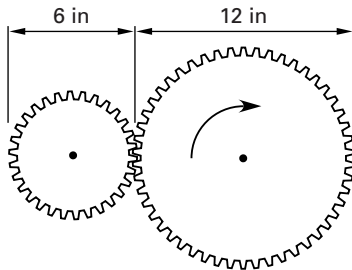
The dynamic equivalent radial load is most nearly

- (A) 900 lbf
- (B) 1300 lbf
- (C) 1400 lbf
- (D) 4700 lbf

Hint: Calculate the dynamic equivalent radial load for each phase and average.

PROBLEM 50

A 12 in diameter gear is spinning at 1250 rpm. 25 hp is applied to the 6 in diameter pinion.



The torque applied to the gear is most nearly

- (A) 53 ft-lbf
- (B) 83 ft-lbf
- (C) 110 ft-lbf
- (D) 210 ft-lbf

Hint: Use the speed of the pinion and the pitch velocity to calculate the transmitted load.

PROBLEM 51

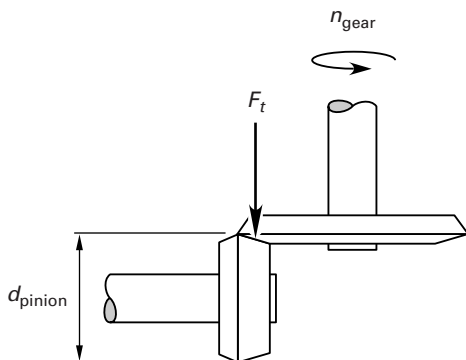
In a set of straight bevel gears, the gear has 96 teeth and a pitch angle of 70° . How many teeth does the pinion have?

- (A) 20
- (B) 35
- (C) 109
- (D) 264

Hint: The tangent of the pitch angle is the ratio of the number of teeth of the gear and pinion.

PROBLEM 52

A bevel gear arrangement is shown. The speed of the gear is raised to 300% from its former rate. The diameter of the pinion is reduced by 50%, and the transmitted load is raised to 400%.



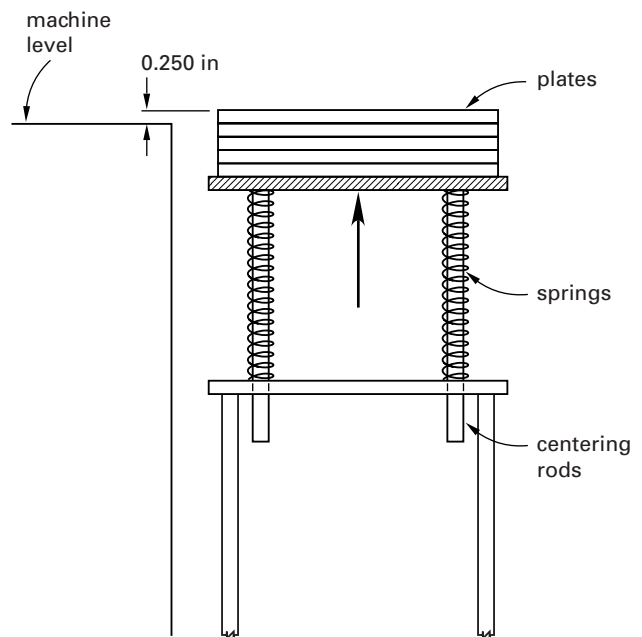
To maintain the system, the horsepower must be changed. The percentage of its former rate that it must be changed to is most nearly

- (A) 17%
- (B) 270%
- (C) 300%
- (D) 600%

Hint: The solution can be found from the relationship of the variables without requiring the actual values.

PROBLEM 53

A pallet loader is a platform supported equally by four identical springs. After the top plate in the stack is removed, the loader raises the remaining plates to machine level in 0.250 in increments. The plates are 0.250 in thick and have a mass of 4.83 lbm. The springs are made of stainless steel wire (ASTM 313) with a wire diameter of 0.187 in. Each spring has 84 coils, with squared and ground ends. Centering rods prevent the springs from buckling.



The maximum diameter of the centering rods is most nearly

- (A) 0.375 in
- (B) 0.750 in
- (C) 1.25 in
- (D) 2.00 in

Hint: Find the inside diameter of the spring.

Why Other Options Are Wrong

(A) This incorrect solution results when the moment of inertia is used instead of the section modulus.

(B) This incorrect solution results when the weight of the platform and safety railing is neglected.

(D) This incorrect solution results when the full length is used to calculate the moment.

APPLICATIONS: MECHANICAL COMPONENTS
SOLUTION 43

A force fit (or shrink fit) is a special type of interference fit. A force fit is characterized by constant bore pressure throughout the range of sizes.

The answer is (C).

Why Other Options Are Wrong

(A) A running and sliding fit would not apply significant pressure to the bearing, allowing it to slip in place. A running and sliding fit is intended for accurate location with lubrication allowance.

(B) A locational fit would determine an accurate location of the bearing, but not a constant pressure. A locational fit is intended to determine only the location of the mating parts.

(D) "Accurate fit" is not a class of fit. The classes of fits are arranged in three general groups: running and sliding fits, locational fits, and force fits.

SOLUTION 44

The total number of revolutions during the rated life of the bearing is

$$\begin{aligned} N_{\text{rev}} &= L_R n_b \\ &= (3000 \text{ hr}) \left(500 \frac{\text{rev}}{\text{min}} \right) \left(60 \frac{\text{min}}{\text{hr}} \right) \\ &= 90 \times 10^6 \text{ rev} \end{aligned}$$

The speed of the winding mechanism is

$$\begin{aligned} n_m &= \frac{v}{C} \\ &= \frac{300 \frac{\text{ft}}{\text{min}}}{0.20 \text{ ft}} \\ &= 1500 \text{ rev/min} \end{aligned}$$

The design life of the bearing in machine hours is

$$\begin{aligned} L_D &= \frac{N_{\text{rev}}}{n_m} \\ &= \left(\frac{90 \times 10^6 \text{ rev}}{1500 \frac{\text{rev}}{\text{min}}} \right) \left(\frac{1 \text{ hr}}{60 \text{ min}} \right) \\ &= 1000 \text{ hr} \end{aligned}$$

The answer is (C).

Why Other Options Are Wrong

(A) This incorrect solution results from not converting the catalog-rated life of the bearing from hours to minutes.

(B) This incorrect solution results from confusing the catalog-rated speed with the speed of the winding mechanism.

(D) This incorrect solution results from using the catalog-rated life of the bearing instead of the required design life.

SOLUTION 45

Calculate the dynamic equivalent radial load for each phase. (The rotation factor, V , equals 1 for a rotating inner race and 1.2 for a rotating outer race.)

$$\begin{aligned} F &= V X F_R + Y F_T \\ F_1 &= (1) (0.4) (250 \text{ lbf}) + (0.4 \cot 20^\circ) (500 \text{ lbf}) \\ &= 649 \text{ lbf} \\ F_2 &= (1) (0.4) (750 \text{ lbf}) + (0.4 \cot 20^\circ) (1000 \text{ lbf}) \\ &= 1399 \text{ lbf} \\ F_3 &= (1) (0.4) (250 \text{ lbf}) + (0.4 \cot 20^\circ) (500 \text{ lbf}) \\ &= 649 \text{ lbf} \end{aligned}$$

The mean load is solved by using Miner's rule, combining and averaging individual loads with exponent p taken as 10/3 for roller bearings.

$$\begin{aligned} F_{\text{mean}} &= \left(\frac{\sum F_i^p n_i t_i}{\sum n_i t_i} \right)^{1/p} \\ &= \left(\frac{F_1^{10/3} n_1 t_1 + F_2^{10/3} n_2 t_2 + F_3^{10/3} n_3 t_3}{n_1 t_1 + n_2 t_2 + n_3 t_3} \right)^{3/10} \end{aligned}$$

(B) This incorrect solution results when the speeds of the ring gear and the sun gear are interchanged as the gear train value is calculated.

(D) This incorrect solution results when the same number of teeth is used for the inside of the ring gear as on the outside.

SOLUTION 50

The speed of the pinion is calculated from the equation

$$\begin{aligned} \frac{d_{\text{gear}}}{d_{\text{pinion}}} &= \frac{n_{\text{pinion}}}{n_{\text{gear}}} \\ n_{\text{pinion}} &= \left(\frac{d_{\text{gear}}}{d_{\text{pinion}}} \right) n_{\text{gear}} \\ &= \left(\frac{12 \text{ in}}{6 \text{ in}} \right) \left(1250 \frac{\text{rev}}{\text{min}} \right) \\ &= 2500 \text{ rpm} \end{aligned}$$

The pitch circle velocity, or tangential velocity, is the same for both gears.

$$\begin{aligned} v_t &= \left(\frac{\pi d_{\text{pinion}}}{1 \text{ rev}} \right) n_{\text{pinion}} \\ &= \left(\frac{\pi(6 \text{ in}) \left(\frac{1 \text{ ft}}{12 \text{ in}} \right)}{1 \text{ rev}} \right) \left(2500 \frac{\text{rev}}{\text{min}} \right) \\ &= 3930 \text{ ft/min} \end{aligned}$$

The transmitted load is

$$\begin{aligned} F_t &= \frac{33,000P}{v_t} \\ &= \frac{\left(33,000 \frac{\text{ft-lbf}}{\text{hp-min}} \right) (25 \text{ hp})}{3930 \frac{\text{ft}}{\text{min}}} \\ &= 210 \text{ lbf} \end{aligned}$$

The applied torque is

$$\begin{aligned} T &= \left(\frac{d}{2} \right) F_t \\ &= \left(\frac{6 \text{ in}}{2} \right) \left(\frac{1 \text{ ft}}{12 \text{ in}} \right) (210 \text{ lbf}) \\ &= 53 \text{ ft-lbf} \end{aligned}$$

The answer is (A).

Why Other Options Are Wrong

(B) This incorrect solution results when the speed of the pinion, instead of the pitch circle velocity, is used to compute the transmitted load.

(C) This incorrect solution results when the diameter, instead of the radius, is used to calculate the applied torque.

(D) This incorrect solution results when the computation stops at the transmitted load instead of continuing to determine the applied torque.

SOLUTION 51

The number of teeth of the pinion is found by using the equation

$$\begin{aligned} \tan \Gamma &= \frac{N_{\text{gear}}}{N_{\text{pinion}}} \\ N_{\text{pinion}} &= \frac{N_{\text{gear}}}{\tan \Gamma} \\ &= \frac{96 \text{ teeth}}{\tan 70^\circ} \\ &= 35 \text{ teeth} \end{aligned}$$

The answer is (B).

Why Other Options Are Wrong

(A) This incorrect solution results when the pitch angle of the pinion is calculated.

(C) This incorrect solution results when the arc tangent of the gear pitch angle, instead of the tangent, is used.

(D) This incorrect solution results when the pitch angle of the pinion, instead of the gear, is used.

SOLUTION 52

The relationships among rotational speed, pinion diameter, transmitted load, and power are given by the equations

$$\begin{aligned} v &\approx \pi d_{\text{pinion}} n_{\text{pinion}} \\ P &\approx F_t v \end{aligned}$$

Combining them,

$$P \approx F_t \pi d_{\text{pinion}} n_{\text{pinion}}$$

Multiplying n_{pinion} by 3, d_{pinion} by 0.5, and F_t by 4 causes P to be multiplied by $(3)(0.5)(4)$, or 6, which equals a 600% increase.

The answer is (D).