INSTRUCTIONS:

This quiz is open-book, open-note, and you may work with your classmates.

GIVEN:

An M14 x 2 bolt with a nut is used to clamp together two 15-mm steel plates. → $l = 30$ mm

FIND:

a) A suitable length for the bolt, rounded up to the nearest 5 mm. → follow process on next page.

b) The bolt stiffness, k_b. see next page

c) The member stiffness, k_m.
Note: because the clamped material is all steel, the following equation can be used.

$$\frac{k_m}{E\,d} = A\,e^{(B\,d/l)}$$

d) The bolt stiffness constant, C.

Table 8–8 Stiffness Parameters of Various Member Materials†

Material Used	Poisson Ratio	Elastic Modulus			
		GPa	Mpsi	A	B
Steel	0.291	207	30.0	0.787 15	0.628 73
Aluminum	0.334	71	10.3	0.796 70	0.638 16
Copper	0.326	119	17.3	0.795 68	0.635 53
Gray cast iron	0.211	100	14.5	0.778 71	0.616 16
General expression				0.789 52	0.629 14

for bolt and km

for km

Source: Data from J. Wileman, M. Choudury, and I. Green, "Computation of Member Stiffness in Bolted Connections," *Trans. ASME, J. Mech.* Design, vol. 113, December 1991, pp. 432–437.

Table A–31 Dimensions of Hexagonal Nuts

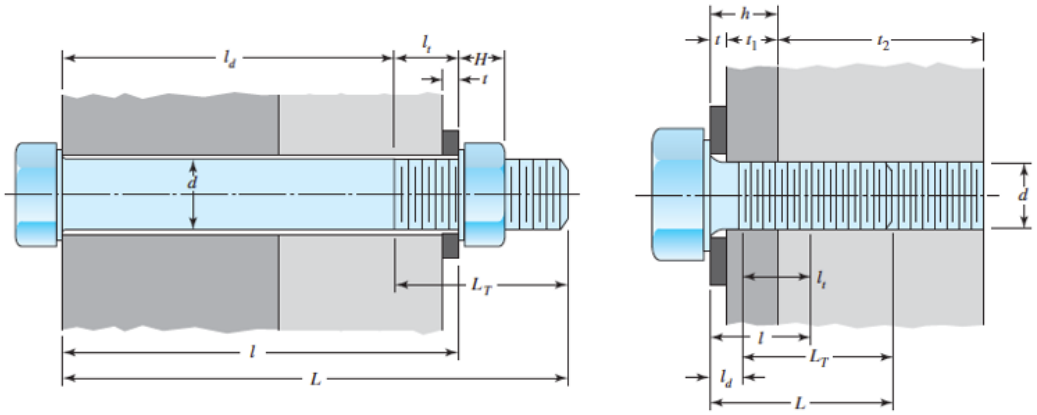
Nominal Size, d mm	Width W	Height H		
		Regular Hexagonal	Thick or Slotted	JAM
M5	8	4.7	5.1	2.7
M6	10	5.2	5.7	3.2
M8	13	6.8	7.5	4.0
M10	16	8.4	9.3	5.0
M12	18	10.8	12.0	6.0
M14	21	12.8	14.1	7.0
M16	24	14.8	16.4	8.0
M20	30	18.0	20.3	10.0
M24	36	21.5	23.9	12.0
M30	46	25.6	28.6	15.0
M36	55	31.0	34.7	18.0

d) $C = \dfrac{k_b}{k_b + k_m} = \dfrac{874.4}{874.4 + 3059} = 0.222$

c) $k_m = 207 \cdot 10^9 \frac{N}{m^2} \cdot 0.014\ m \cdot 0.78715 \exp(0.62873 \cdot 14/30)$

$= 3059\ MN/m$

Table 8–7 Suggested Procedure for Finding Fastener Stiffness



Given fastener diameter d and pitch p in mm or number of threads per inch

Washer thickness: t from Table A–32 or A–33 NA

Nut thickness [Figure (*a*) only]: H from Table A–31 = 12.8 mm (page 1)

Grip length:

For Figure (*a*): l = thickness of all material squeezed between face of bolt and face of nut = 30 mm

For Figure (*b*): $l = \begin{cases} h + t_2/2, & t_2 < d \\ h + d/2, & t_2 \geq d \end{cases}$

Fastener length (round up using Table A–17*):

For Figure (*a*): $L > l + H$ = 30 + 12.8 = 42.8 → choose 45 mm (ans a)

For Figure (*b*): $L > h + 1.5d$

Threaded length L_T: Inch series:

$$L_T = \begin{cases} 2d + \frac{1}{4}\text{ in}, & L \leq 6\text{ in} \\ 2d + \frac{1}{2}\text{ in}, & L > 6\text{ in} \end{cases}$$

Metric series:

$$L_T = \begin{cases} 2d + 6\text{ mm}, & L \leq 125\text{ mm}, d \leq 48\text{ mm} \\ 2d + 12\text{ mm}, & 125 < L \leq 200\text{ mm} \\ 2d + 25\text{ mm}, & L > 200\text{ mm} \end{cases}$$ = 2·14+6 = 34mm

Length of unthreaded portion in grip: $l_d = L - L_T$ = 45 − 34 = 11 mm

Length of threaded portion in grip: $l_t = l - l_d$ = 30 − 11 = 19 mm

Area of unthreaded portion: $A_d = \pi d^2/4$ = π (14)²/4 = 153.9 mm²

Area of threaded portion: A_t from Table 8–1 or 8–2 = 115 mm²

Fastener stiffness: $k_b = \dfrac{A_d A_t E}{A_d l_t + A_t l_d}$

*Bolts and cap screws may not be available in all the preferred lengths listed in Table A–17. Large fasteners may not be available in fractional inches or in millimeter lengths ending in a nonzero digit. Check with your bolt supplier for availability.

$$k_b = \frac{153.9\text{ mm}^2 \cdot 115\text{ mm}^2 \cdot 207 \cdot 10^9\text{ N/m}^2}{(153.9\text{mm}^2)(19\text{ mm}) + (115\text{ mm}^2)(11\text{ mm})} = 847 \cdot 10^9 \frac{\text{N}}{\text{m}^2} \cdot \text{mm}$$

= 874.4 MN/m ← ans. (b)