I am a graduating senior – circle one: Yes  No

READ THE FOLLOWING GENERAL EXAMINATION RULES:

1) Do not put your completed work anywhere that it can be seen. If any part of your work can be seen by others it will be confiscated and you will not be permitted to rework those problems. Place any pages of your work face down on your desk under your existing work, not on the floor next to you where it is visible.

2) Please remove your hat. If it is part of your head, turn it around backwards.

3) If your work is not legible, or if I cannot follow your logic at a glance, it will receive no credit. This paper must be written to acceptable engineering standards for credit. Please take this seriously as it will affect your grade.

4) You may work on the front or back of this paper. Just note if any work is on the back.

5) You can use your own paper or paper supplied at the front of the room.

6) You MUST specify what you are doing every step of the way. You MUST list the table number and/or manual page number that you are using throughout your solutions, for credit. If you mentally check something but don’t write down why you have decided it is OK, I must assume that no check was performed. If I can follow where you got your numbers from, you will likely receive partial credit should you go off track.

7) Write big and use lots of paper, leaving me room to grade your paper. If there is no room to tell you why points were deducted, I will only show you the point deduction and let you try and figure out why.

8) You must present your work in a linear fashion, i.e. state what limit state you are checking and then write down all necessary calculations you used in determining that value. Be sure to denote which of the possible answers you are finally selecting.

9) If you find any information that you think is missing that is necessary to get a solution, it will be in your best interest to at least go ahead and make your best engineering judgment for it and proceed with the solution, rather than just giving up.

I have read and understand all of the above instructions: ___________ (Initials)

Ethical Standards:

Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning, and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the TAMU community from the requirements or the processes of the Honor System.

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."

__________________________
Signature of student

Please do not open this exam until you are told to do so.
Problem 1) (20 points) A bracket cut from a WT6x32.5 is connected to a W13x65 column flange with 3/8 inch A490 bolts in a bearing type connection and subjected to service loads $P_{\text{dead}} = 30 \text{ k}$ and $P_{\text{live}} = 70 \text{ k}$. Determine if the bolts are adequate to carry the load. Use $x = 2$, $y = 1$. You can neglect any prying action and assume that the connected parts have adequate thickness so that bearing does not control. No other limit states than the capacity of the bolts need to be checked, including GSY, NDR, BSR.

\[ P_u = 1.2(30) + 1.6(70) = 148 \text{ k} \]
\[ T_u = \left(\frac{2}{\sqrt{3}}\right)(148) = 132.4 \text{ k}^2 \]
\[ V_u = \left(\frac{1}{\sqrt{3}}\right)(148) = 66.2 \text{ k} \]
\[ T_{\text{bolt}} = 132.4 \times \frac{1}{6} = 22.1 \text{ k/Bolt} \]
\[ V_{\text{bolt}} = 66.2 \times \frac{1}{6} = 11.0 \text{ k/Bolt} \]

A bolt = 0.442 in$^2$, Table J3.2 pg [16.1 – 120] $\frac{\sqrt{2}}{2}$ A490N:
\[ F_{nt} = 113 \text{ ksi}, \quad F_{nv} = 68 \text{ksi}, \quad F_{nv} = 113 \times 0.442 \text{ in}^2 = 24.9 < 68 \text{ k} \]

Left for you in presence of shear $F_{nt} = 1.3 F_{nt} - \frac{F_{nt} - F_{nv}}{\phi F_{nv}} \leq F_{nt}$
\[ F'_{nt} = 1.3 \left(\frac{113}{0.75}\right) \left(\frac{24.9}{68}\right) = 91.8 \text{ksi} \]

Shear in your bolt \( \phi \)

Then permitted allowed tension load in your bolt:
\[ \phi F'_{nt} A_b = \left(\frac{0.75}{91.8 \text{ksi}}\right) (0.442 \text{in}^2) \]
\[ = 30.4 \text{ kips/bolt} > \text{request of 22.1 k/Bolt} \]

So bolts are OK.

(Must assume threaded)
Problem 2) (20 points) Determine the maximum factored tension load, \( P_u \), that can be applied to the pair of angles and gusset plate shown. All members are A36 steel. The angles are 5 x 3-1/2 x 5/16” with the long legs back to back. The angles overlap the gusset plate by 7 inches. The gusset plate is 1/2” thick. Both angles are welded to the gusset plate as shown using 3/16” fillet welds on the two sides, and on the ends, with appropriate electrodes. You do not have to check the strength of the base metal under the weld, but you must check all other appropriate limit states for the members.

\[ GSY: P_u = 0.9 F_y A_g = 0.9 (36 ksi) (2.56 \text{ in}^2) = 83 \times 2 = 166 \text{ k} \]

\[ NSR: U = 1 - \frac{F_y}{F_u} = 1 - \frac{0.829 \text{ in}}{7''} = 0.882 \]

\[ A_e = 2.56 \text{ in}^2 (0.882) = 2.26 \text{ in}^2 \]

\[ P_u = 0.75 (58 \text{ ksi}) (2.26 \text{ in}^2) = 98.2 \text{ k} \times 2 \]

For Plate: \( A_{g,w} = 2(7'') (V/2') = 7 \text{ in}^2 \text{ Amw}, A_{nt} = 5(1/2) = 2.5 \text{ in}^2 \)

\[ P_u = 0.75 (0.6 F_u A_{g,w} + U_{be} F_u A_{nt}) = 0.75 (0.6 \times 58 \times 7 + 1.0 \times 58 \times 2.5) = 291 \text{ k} \]

\[ a P_u = 0.75 (0.6 F_y A_{g,w} + U_{be} F_u A_{nt}) = 2.222 \text{ k} \times [J4-5] \]

For Weld: \( F_{m,w} = 0.75 (0.6) (F_{w,k}) (0.707\mu) = 4.176 \text{ k/in} \)

\[ \frac{F_{m,w}}{3/16''} = 1.391 \frac{\text{k/in}}{\text{per 1/16'' weld}} \times \text{3 sixteenths} = 4.176 \text{ k/in} \]

Using 4.176 k/in all around: \( P_u = 4.176 \text{k/in} (7'' + 5'') = 79.34 \text{k} \)

\[ 1.5 (4.176 \text{ on end}) + 0.85 (4.176 \text{ on sides}) \]

\[ P_u = 1.5 (4.176 \text{k/in}) (5'') + 0.85 (4.176 \text{k/in}) (7'' + 7'') = 81 \text{k} \]

Use larger \( \times 2 \) angles

So weld controls: \( P_u = 81 \text{k} \)

For 2 angles: \( P_u = 162 \text{k} \)
Problem 3) (20 points) Given, a double angle tension member composed of 2 – L4x3x1/2". Seven-eights inch diameter A325N bolts are used to connect the angles to a 3/8" gusset plate in a slip critical connection with standard holes and Class A surfaces. A36 steel is used throughout. Determine the maximum factored load that can be carried based only on bearing, and the capacity of the bolts. You need not check any other limit states (GSY, NSR, BSR, etc.) as these checks are being made by others.

See next page
Problem 1) (20 points) Given a double angle tension member composed of 2 - L4x3x1/2".
Seven-eighths inch diameter A325N bolts are used to connect the angles to a 3/8" gusset plate in a slip critical connection with standard holes and Class A surfaces. A36 steel is used throughout. Determine the maximum factored load that can be carried based only on bearing, and the capacity of the bolts. You need not check any other limit states (GSY, NSR, BSR, etc.) as these checks are being made by others.

**Minimum Spacing:**

\[
S > \frac{d}{3} = \frac{2}{3}(\frac{7}{8}) = 2.33 < 3
\]

\[
l_e > 1.5 \left(16.1 - 123\right) = 2 > 1.8
\]

**Bearing Strength:**

\[
h = \frac{t}{8} + \frac{1}{16} = 0.9375"
\]

**Edge Bolts:**

\[
l_c = l_e - \frac{h}{2} = 2 - \frac{0.9375}{2} = 1.53125"
\]

\[
R_n = 1.2 l_c t f_u = 1.2 \left(1.53125\right) \left(\frac{2}{8}\right) (58) = 39.97 \frac{k}{\text{bolts}}
\]

\[
2.4 d_t f_u = 2.4 \left(\frac{7}{8}\right) (58) = 45.62 \frac{k}{\text{bolts}} > 39.97 \Rightarrow \text{USE THIS}
\]

**Interior Bolts:**

\[
l_c = S - h = 3 - 0.9375 = 2.0625"
\]

\[
1.2 l_c t f_u = 1.2 \left(2.0625\right) \left(\frac{2}{8}\right) (58) = 53.83 > 45.62 \Rightarrow \text{USE THIS}
\]

\[
\phi R_n = \left(1\right)(39.97) + 4 \left(45.62\right) = \overline{0.78 = 167 k}
\]

**Slip-Critical:**

\[
\phi R_n = R_n = M d_u h f T_b \ n s
\]

\[
M = 6.3 \quad d_u = 1.13 \quad h_f = 1 \quad T_b = 39 k \quad [T. J 3.1]
\]

\[
\phi R_n = (0.1)(1.13)(179)(5) = 66.1 \text{ (FOR ONE ANGLE)}
\]

\[
N_s = 5
\]

\[
\phi R_n = 2(66.1) = 132.2 k
\]

\[
\Rightarrow \text{SLIP-CRITICAL CONTROLS}
\]
Problem 4) (20 points) The bolt group shown consists of A325N bolts in a single shear bearing connection. Determine the required bolt diameter to handle a factored load $P = 50$ kips applied as shown using the method of instantaneous centers (the ultimate analysis method) using the AISC tables. You can assume that the bearing strength of the connected parts does not control.

Table 7-6

$P_u = \phi R_m = \phi C R_n$

$= \phi C F_{min} A_b \quad [16.1-120]

50$ $K = 0.75(4.47) 54 \text{ksi } A_b \quad [7-30]$

$s_0 A_b = 50^K \frac{1N^2}{0.75(4.47)54k} = 0.296 \text{in}^2$

From [7-22] use 5/8" bolts ($A_b = 0.307\text{in}^2$)

OR: $R_u = C \phi R_n$

$s_0 \phi R_n = R_u = \frac{50^K}{4.47} = 11.2 K/\text{BOLT}$

Then from Table 7-1 pg. 7-22

Use 5/8" bolts @ $\phi R_n = 12.4$
### Table 7-6

**Coefficients C for Eccentrically Loaded Bolt Groups**

**Angle = 0°**

Available strength of a bolt group, \( \phi R_n \) or \( P_n/\phi_2 \), is determined with

\[
R_n = C \times r_n
\]

or

\[
C_{\text{min}} = \frac{P_n}{\phi_2 R_n}
\]

Where:

- \( P \) = required force, \( P_u \) or \( P_e \) kips
- \( r_n \) = nominal strength per bolt, kips
- \( e \) = eccentricity of \( P \) with respect to centroid of bolt group, in.
  (not tabulated, may be determined by geometry)
- \( e_x \) = horizontal component of \( e \), in.
- \( s \) = bolt spacing, in.
- \( C \) = coefficient tabulated below

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\[ C', \text{ in.} \]

2.94 5.89 11.3 17.1 25.1 33.8 44.4 55.9 69.2 83.5 100

\[ C', \text{ in.} \]

5.89 11.8 22.5 34.3 50.2 67.6 88.8 112 138 167 199
## Table 7-1
### Available Shear Strength of Bolts, kips

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<th>$\phi F_{uv}$ (ksi)</th>
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Problem 5) (20 Points) Solve for the factored load which can be placed on the pair of angles shown, using the ultimate strength method (use the tables in Part 8 of the AISC Manual). Use the information shown in the figure, and d = 10 inches.
$\phi R_m = 1.19 \quad 1.28 \quad 2.6 \quad 1.28 \quad 2.666$  

so $P_u = 28.1 k$ per angle

interpolated $1.19 \quad 1.25 \quad 2.5$  

$a = e_x = 13.33$  

$0 = x = 10'' + (5 - a_l)$  

$e_x = 0.333$  

$a_l = 5'' + (5 - 0.333(5))$  

$k_l = 5''$
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**Table 8-8**

**Coefficients, \( C \),**

**for Eccentrically Loaded Weld Groups**

**Angle = 0°**

Available strength of a weld group, \( \phi R_a \) or \( R_a/\Omega \), is determined with

\[
R_a = C \frac{D}{l}
\]

where

\( P \) = required force, \( R_a \) or \( R_a/\Omega \), kips

\( D \) = number of sixteenths-of-an-inch in the fillet weld size

\( l \) = characteristic length of weld group, in.

\( a = \frac{e_a}{l} \)

\( e_a \) = horizontal component of eccentricity of \( P \)

with respect to centroid of weld group, in.

\( C = \) coefficient tabulated below

\( C_1 = \) electrode strength coefficient from Table 8-3

(1.0 for E70XX electrodes)

Note: Shaded values indicate the value is based on the greatest available strength permitted by AISC Specification Sections J2.4, J2.4(a), J2.4(b) and J2.4(c).
I am a graduating senior – circle one: Yes  No

READ THE FOLLOWING GENERAL EXAMINATION RULES:

1) Do not put your completed work anywhere that it can be seen. If any part of your work can be seen by others it will be confiscated and you will not be permitted to rework those problems. Place any pages of your work face down on your desk under your existing work, not on the floor next to you where it is visible.
2) Please remove your hat. If it is part of your head, turn it around backwards.
3) If your work is not legible, or if I cannot follow your logic at a glance, it will receive no credit. This paper must be written to acceptable engineering standards for credit. Please take this seriously as it will affect your grade.
4) You may work on the front or back of this paper. Just note if any work is on the back.
5) You can use your own paper or paper supplied at the front of the room.
6) You MUST specify what you are doing every step of the way. You MUST list the table number and/or manual page number that you are using throughout your solutions, for credit. If you mentally check something but don’t write down why you have decided it is OK, I must assume that no check was performed. If I can follow where you got your numbers from, you will likely receive partial credit should you go off track.
7) Write big and use lots of paper, leaving me room to grade your paper. If there is no room to tell you why points were deducted, I will only show you the point deduction and let you try and figure out why.
8) You must present your work in a linear fashion, i.e. state what limit state you are checking and then write down all necessary calculations you used in determining that value. Be sure to denote which of the possible answers you are finally selecting.
9) If you find any information that you think is missing that is necessary to get a solution, it will be in your best interest to at least go ahead and make your best engineering judgment for it and proceed with the solution, rather than just giving up.

I have read and understand all of the above instructions: ____________  (Initials)

Ethical Standards:

Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning, and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the TAMU community from the requirements or the processes of the Honor System.

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."

______________________________
Signature of student

Please do not open this exam until you are told to do so.
Problem 1) (20 points) Given, a double angle tension member composed of 2 – 1.4x3x1/2".
Seven-eights inch diameter A325N bolts are used to connect the angles to a 3/8" gusset plate in a slip critical connection with standard holes and Class A surfaces. A36 steel is used throughout. Determine the maximum factored load that can be carried based only on bearing, and the capacity of the bolts. You need not check any other limit states (GSY, NSR, BSR, etc.) as these checks are being made by others.

Same as Problem 3, Quiz #1
Problem 2) (20 points) A bracket cut from a WT6x32.5 is connected to a W13x65 beam flange with \( \frac{3}{4} \) inch A490 bolts in a bearing type connection and subjected to service loads \( P_{\text{dead}} = 30 \text{ k} \) and \( P_{\text{live}} = 70 \text{ k} \). Determine if the bolts are adequate to carry the load. Use \( x = 1, y = 2 \). You can neglect any prying action and assume that the connected parts have adequate thickness so that bearing does not control. No other limit states than the capacity of the bolts need to be checked, including GSY, NDR, BSR.

Same as Problem 1 or Quiz 1
Problem 3) (20 points) Determine the maximum factored tension load, $P_u$, that can be applied to the pair of angles and gusset plate shown. All members are A36 steel. The angles are 5 x 3-1/2 x 5/16" with the long legs back to back. The angles overlap the gusset plate by 6 inches. The gusset plate is 3/8" thick. Both angles are welded to the gusset plate as shown using 3/16" fillet welds on the two sides, and on the ends, with appropriate electrodes. You do not have to check the strength of the base metal under the weld, but you must check all other appropriate limit states for the members.

See next page

Only change is $t_{gusset plate}$ to 3/8"

& overlap goes from 7" to 6".
Problem 6 (20 points) Determine the maximum factored tension load, \( P_u \), that can be applied to the pair of angles and gusset plate shown. All members are A36 steel. The angles are 5 x 3-1/2 x 5/16" with the long legs back to back. The angles overlap the gusset plate by 6 inches. The gusset plate is 3/8" thick. Both angles are welded to the gusset plate as shown using 3/16" fillet welds on the two sides, and on the ends, with appropriate electrodes. You do not have to check the strength of the base metal under the weld, but you must check all other appropriate limit states for the members.

\[
\text{GUSY: } P_u = 0.9 F_y A_g = 0.9(36 \text{ ksi})(2.56 \text{ in}^2) = 83,320 \text{ lb}
\]

\[
\text{NSR: } U = 1 - \frac{A_e}{A} = 1 - \frac{2.56}{6} = 0.862
\]

\[
A_e = 2.56 \text{ in} \times 0.862 = 2.21 \text{ in}
\]

\[
P_u = 0.75 \left( 58 \text{ ksi} \right) \left( 2.21 \text{ in}^2 \right) = 92.1 \text{ k}
\]

\[
\text{For Plate: } A_{gw} = 2(6") \times 3/8") = 4.5 \text{ in}^2 = A_{mw}; \text{ Ant = 5/8"; } P_u = 0.75 \left( 0.6 \text{ Fu} A_{mw} + U_{be} F_u \text{ Ant} \right) = 0.75 \left( 0.6 \times 58 \times 4.5 + 1 \times 58 \times 0.87 \right) = 198.2 \text{ k}
\]

\[
\text{or } P_u = 0.75 \left( 0.6 F_y A_{gw} + \frac{U_{be}}{4} F_u \text{ Ant} \right) = 0.75 \left( 0.6 \times 36 \times 4.5 + 0.5 \times 58 \times 1.87 \right) = 154.5 \text{ k}
\]

\[
\text{For Weld: } \phi_{m} = 0.75 \left( 0.6 \right) \left( F_{exx} \right) (0.707 \text{ in}) = 4,176 \text{ lb/in}
\]

\[
\text{or } \phi_{m} = 1,391 \text{ k/in} \times 3/16" = 4,176 \text{ lb/in}
\]

Using 4.176 k/in all around: \( P_u = 4,176 \text{ lb/in} \times (6 + 5 + 6) = 71.0 \text{ k}
\]

\[
\text{or } 1.5(4,176 \text{ on end}) + 0.85(4,176 \text{ on sides})
\]

\[
P_u = 1.5 \left( 4,176 \text{ k/in} \right) (5") + 0.85 \left( 4,176 \text{ k/in} \right) (6 + 6) = 73.92 \text{ k}
\]

\[
\text{Use larger } x 2 \text{ angles}
\]

\[
\text{For Langle weld } P_u = 73.92 \text{ k}
\]

\[
\text{For 2 angles: } P_u = 147.8 \text{ k Controls}
\]
Problem 4) (20 Points) Solve for the factored load which can be placed on the pair of angles shown, using the ultimate strength method (use the tables in Part 8 of the AISC Manual). Use the information shown in the figure, and \( d = 8 \) inches.

See next page
\[ l = 5'' \]

\[ k = 5'' \]

So \( k = 1.0 \)

\[ \alpha = 0.333 \]

\[ \alpha = \theta'' + (5 - \alpha l) \]

\[ = 8'' + (5 - 0.333(5)) \]

\[ = 11.333 \]

So since \( E = \alpha l \)

\[ a = E/\ell = 11.333/5'' = 2.266 \]

\[ \Phi_{RC} = \phi C C_1 D l = 0.75(1.46)(1.0)(3)(5'') \]

\[ = 16.42 \text{ K per angle} \]

So \( P_u = 32.9 \text{ K} \)
Table 8-8  
Coefficients, C, for Eccentrically Loaded Weld Groups  
\( \text{Angle} = 0^\circ \)

Available strength of a weld group, \( \phi R_n \) or \( R_n/\Omega \), is determined with  
\[ R_n = CC_i D \text{i} \]  
\( R_n = 0.75, \ D_i = 2.00 \)

<table>
<thead>
<tr>
<th>LRFD</th>
<th>ASD</th>
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<tr>
<td>( C_{min} = \frac{P_n}{\phi C_i D} )</td>
<td>( C_{min} = \frac{\Omega P_n}{CC_i D} )</td>
</tr>
<tr>
<td>( D_{min} = \frac{P_n}{\phi C_i D} )</td>
<td>( D_{min} = \frac{\Omega P_n}{CC_i D} )</td>
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<tr>
<td>( l_{min} = \frac{P_n}{\phi C_i D} )</td>
<td>( l_{min} = \frac{\Omega P_n}{CC_i D} )</td>
</tr>
</tbody>
</table>

where  
\( \phi = \text{required force, } P_n \) or \( P_a, \text{ kips} \)
\( D = \text{number of sixteenths-of-an-inch in the fillet weld size} \)
\( I = \text{characteristic length of weld group, in.} \)
\( a = \frac{e_i}{l} \)

\( e_i = \text{horizontal component of eccentricity of } P \)  
with respect to centroid of weld group, in.
\( C = \text{coefficient tabulated below} \)
\( C_i = \text{electrode strength coefficient from Table 8-3} \)  
(1.0 for E70XX electrodes)

Note: Shaded values indicate the value is based on the greatest available strength permitted by AISC Specification Sections J2.4, J2.4(a), J2.4(b) and J2.4(c).

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AMERICAN INSTITUTE OF STEEL CONSTRUCTION
Problem 5) (20 points) The bolt group shown consists of A325N bolts in a single shear bearing connection. Determine the required bolt diameter to handle a factored load $P = 80$ kips applied as shown using the method of instantaneous centers (the ultimate analysis method) using the AISC tables. You can assume that the bearing strength of the connected parts does not control.

Table 7-6 [F-30]

<table>
<thead>
<tr>
<th>$P_u$</th>
<th>$\phi R_m$</th>
<th>$\phi C R_m$</th>
</tr>
</thead>
</table>

$$P_u = \phi R_m = \phi C R_m$$

$$= \phi C F_{mn} A_b \quad [16.1-120]$$

$$S_0 = 80 K = 0.75 (4.47) 54 \text{ksi} A_b$$

$$S_0 A_b = \frac{80 K}{0.75 (4.47) 54 K} = 0.442 \text{in}^2$$

Use $\frac{3}{4}'' \phi$ bolts

OR: $R_u = C \phi R_m$

$$\phi R_m = \frac{R_u}{C} = \frac{80 K}{4.47} = 17.9 \frac{K}{\text{bolt}}$$

From table 7-1, use $\frac{3}{4}'' \phi$ bolts
Table 7-6
Coefficients C for Eccentrically Loaded Bolt Groups
Angle = 0°

Available strength of a bolt group, \( \phi R_n \) or \( R_n^\prime/\phi \), is determined with

\[
R_n = C \times r_n
\]

where

- \( P \) = required force, \( P_u \) or \( P_b \) kips
- \( r_n \) = nominal strength per bolt, kips
- \( e \) = eccentricity of \( P \) with respect to centroid of bolt group, in.
  (not tabulated, may be determined by geometry)
- \( e_x \) = horizontal component of \( e \), in.
- \( s \) = bolt spacing, in.
- \( C \) = coefficient tabulated below

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\[ C', \text{ in.} \] = \frac{P_u}{\phi r_n} = \frac{P_b}{r_n^\prime/\phi}