David Dammar

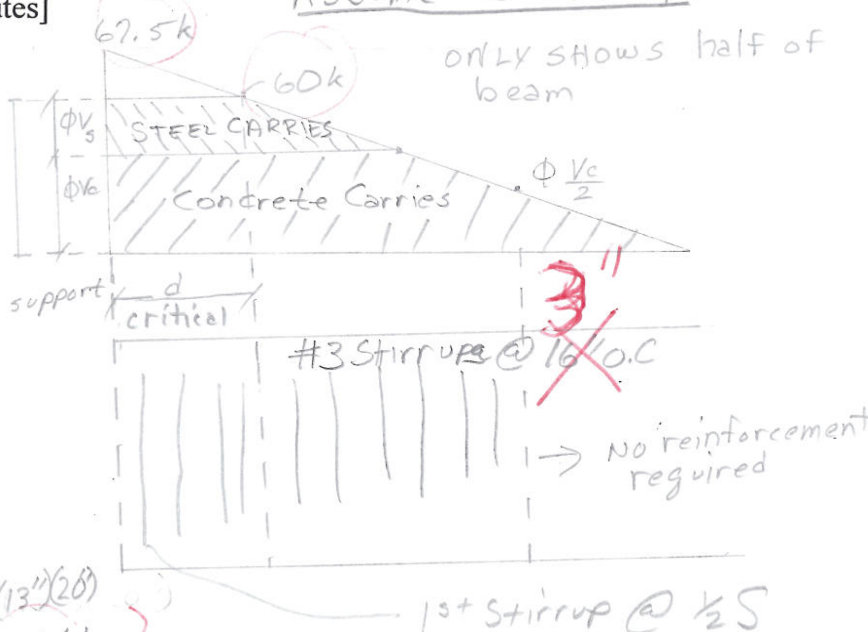
82/100

Place only your student identification number on this test (on all pages). Do not place your name on the test. Do all of your work on the pages provided. If you must separate the pages, staple them back together before surrendering your test. The credit and approximate time that it should take you to work each problem is provided in the square brackets [ ]. It is smarter to attempt all of the problems than to spend most of your time on one problem. You may use your ACI concrete code and the reference sheets that are provided for your use; no other materials are allowed.

1. Determine the required size and spacing of vertical U-stirrups for a 30 foot span, simply supported beam.
   [40 points, 30 minutes]

b_w = 13 in.
d = 20 in.
f_c' = 3,000 psi
f_{yt} = 40,000 psi
w_u = 4.5 kips/ft

Assume #3 Stirrups



① determine Vu@d from support critical shear

$V_u@d = 67.5 - \frac{20}{12}(4.5)$
$= 60k$

② Calculate ϕV_c

$\phi V_c = \phi 2 \sqrt{f_c'}\, b_w d$
$\phi V_c = (0.75)(2)\sqrt{3ksi}(13'')(20'')$
$= 21{,}361\# \approx 21.4k$

③ Is shear reinforcement required

$V_u > \frac{\phi V_c}{2}$
$67.5k > 10.7k$ yes reinforcement is required

④ Determine $V_{s,req}$; $V_{s,max}$

$V_u@d = \phi V_c + \phi V_s \Rightarrow 67.5k - 21.4k = 46.1k = \phi V_s$
$V_{s,req} = \frac{\phi V_s}{\phi} = 46.1k$
$V_{s,max} = 4\sqrt{f_c'}\, b_w d = 4\sqrt{3ksi}(13'')(20'') = 56{,}963 \approx 57.0k$

⑤ max spacing min $\begin{cases} d/2 = 10'' \leftarrow \\ 24'' \end{cases}$

⑥ Determine S critical $S \leq \frac{2 A_v f_y d}{V_s} = \frac{(2)(0.11)(40ksi)(20'')}{46.1k}$

$S \leq 3.8''$ or $0.318 ft$

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7) Determine max S to provide $A_{v,min}$

$A_{v,min} = 0.75\sqrt{f'_c}\,\frac{b_w S}{f_{yt}} = 2(0.11) = 0.75\sqrt{f'_c}\,\frac{(13)\,S}{40ksi}$

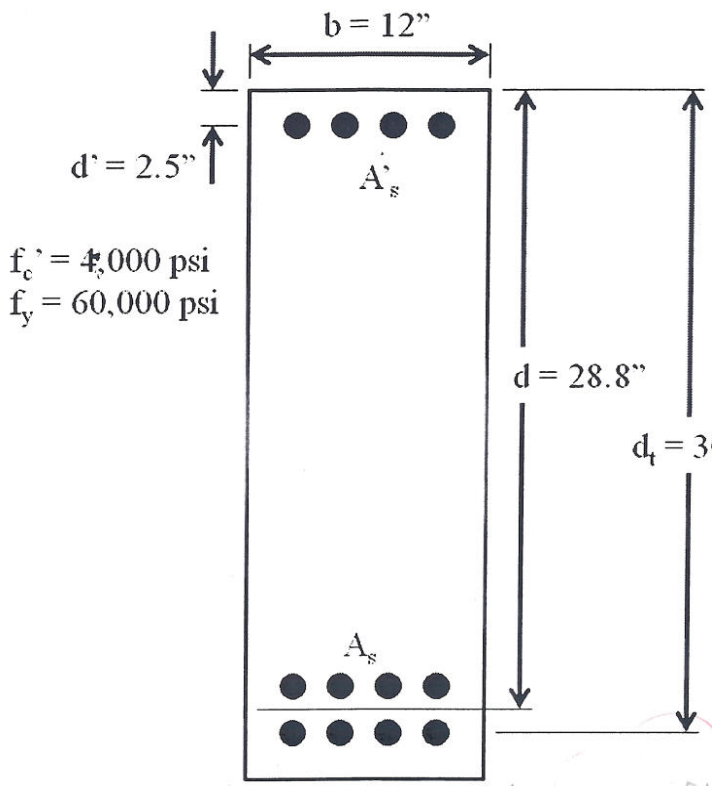
$S = 16.5''$ but not less than $50\,b_w$

then what? you're so close...

+30/40

2. A beam cross section is limited to the size shown. Determine the required area of reinforcement for service load moments $M_D = 490$ ft-kips and $M_L = 190$ ft-kips. [40 points, 30 minutes]

Assume $\phi = 0.90$



① $1.2(490\ ft\text{-}k) + 1.6(190\ ft\text{-}k) = 892\ ft\text{-}k = M_u$

② $M_{n,req} = \frac{M_u}{\phi} = \frac{892\ ft\text{-}k}{0.90} = 991\ ft\text{-}k = 11{,}892\ in\text{-}k$

③ $A_{s1} = \rho_{max}\, b_w d = 0.0181(12")(28.8") = 6.3\ in^2$

④ $\frac{M_u}{\phi b d^2} = 912.0$ $\quad M_{u1} = \phi b_w d^2 \left(\frac{M_u}{\phi b d^2}\right) = (0.9)(12)(30)^2(912.0) = 24.6\ ft\text{-}k$

$M_{n1} = \frac{M_{u1}}{\phi} = \frac{24.6\ ft\text{-}k}{0.9} = 27.3\ ft\text{-}k \Rightarrow M_{n2} = 991\ ft\text{-}k - 27.3\ ft\text{-}k$
$M_{n2} = 964\ ft\text{-}k$

⑤ $a = \frac{A_{s1} f_y}{0.85 f'_c b} = \frac{6.3\ in^2 (60\ ksi)}{(0.85)\, 4\ ksi\, (12)} = 9.26$

$c = \frac{9.26}{0.85} = 10.9$

$\epsilon'_s = \left(\frac{c - d'}{c}\right) 0.003 = \left(\frac{10.9 - 2.5}{10.9}\right) 0.003 = 0.0023 > 0.00207$
$\therefore$ steel yields

⑥ $A_{s1} = \frac{M_{n2}}{f_y (d - d')} = 0.61\ in^2$

wrong d

math error ?

680.8

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$A_s' f_s' = A_{s_2} f_y \therefore A_s' = A_{s_2} \frac{f_s'}{f_y} = A_{s_2} = 0.61 in^2$

$A_s = A_{s_1} + A_{s_2} = 6.3 in^2 + 0.61 in^2 = 6.9 in^2$

$\frac{38}{40}$

3. Answer the following questions. Your answer must fit in the space provided! [20 points, 15 minutes]

   a. What is aggregate interlock, and where is it likely to be considered in reinforced concrete design?

      Aggregate interlock is where the interferres with the steel bonding to the concrete

   b. What two sizes of cylinder molds are used for concrete testing in the State of Louisiana?

      4 x 8 ; 6 x 12

   c. Name and explain the three mechanisms contributing to bond.

      mechanical Interlock

      Adhesion between steel & concrete

      Frictional resistance - gripping of the bar by drying shrinkage

+ 14/20

Table 3.9.3 Minimum Beam Width (inches) To Satisfy 2 Bar Diameters Clear Spacing

BAR SIZE	2	3	4	5	6	7	8
	NUMBER OF BARS IN SINGLE LAYER						
#4	6.8	8.3	9.8	11.3	12.8	14.3	15.8
#5	7.1	9.0	10.9	12.8	14.6	16.5	18.4
#6	7.5	9.8	12.0	14.3	16.5	18.8	21.0
#7	7.9	10.5	13.1	15.8	18.4	21.0	23.6
#8	8.3	11.3	14.3	17.3	20.3	23.3	26.3
#9	8.6	12.0	15.4	18.8	22.2	25.6	28.9
#10	9.1	12.9	16.7	20.5	24.3	28.1	31.9
#11	9.5	13.7	17.9	22.2	26.4	30.6	34.9
#14	12.2	15.9	20.9	26.0	31.1	36.2	41.2
#18	15.0	19.8	26.6	33.3	40.1	46.9	53.7

Table Assumptions:

a. Side cover 1.5 in. each side.
b. #3 stirrups for bars #11 and smaller.
c. #4 stirrups for bars #14 and #18.
d. Since stirrups are bent around 4 stirrup bar diameters, the distance from centroid of bar nearest side face of beam to inside face of #3 stirrup is taken as 0.75 in. for bars #11 and smaller; and equal to the bar radius for #14 and #18 bars.

able 3.9.2 Minimum Beam Width (Inches) According to the ACI Code[a]

IZE OF ARS	2	3	4	5	6	7	8	ADD FOR EACH ADDED BAR
	NUMBER OF BARS IN SINGLE LAYER OF REINFORCEMENT							
#4	6.8	8.3	9.8	11.3	12.8	14.3	15.8	1.50
#5	6.9	8.5	10.2	11.8	13.4	15.0	16.7	1.63
#6	7.0	8.8	10.5	12.3	14.0	15.8	17.5	1.75
#7	7.2	9.0	10.9	12.8	14.7	16.5	18.4	1.88
#8	7.3	9.3	11.3	13.3	15.3	17.3	19.3	2.00
#9	7.6	9.8	12.2	14.3	16.6	18.8	21.1	2.26
#10	7.8	10.4	12.9	15.5	18.0	20.5	23.1	2.54
#11	8.1	10.9	13.8	16.6	19.4	22.2	25.0	2.82
#14	8.9	12.3	15.7	19.1	22.5	25.9	29.3	3.40
#18	10.6	15.1	19.6	24.1	28.6	33.1	37.6	4.51

ble shows minimum beam widths when #3 stirrups are used.
r additional bars, add dimension in last column for each added bar.
r bars of different size, determine from table the beam width for smaller size bars and en add last column figure for each larger bar used.

ssumes maximum aggregate size does not exceed three-fourths of the clear space tween bars (ACI-3.3.2). Table computation procedure is in agreement with the ACI Code erpretation of ACI Committee 340, as used in the *Strength Design Handbook* [2.20].

Table 3.9.4 Minimum Beam Width (inches) To Satisfy 3 Bar Diameters Clear Spacing

BAR SIZE	2	3	4	5	6	7	8
	NUMBER OF BARS IN SINGLE LAYER						
#4	7.3	9.3	11.3	13.3	15.3	17.3	19.3
#5	7.8	10.3	12.8	15.3	17.8	20.3	22.8
#6	8.3	11.3	14.3	17.3	20.3	23.3	26.3
#7	8.8	12.3	15.8	19.3	22.8	26.3	29.8
#8	9.3	13.3	17.3	21.3	25.3	29.3	33.3
#9	9.8	14.3	18.8	23.3	27.8	32.3	36.8
#10	10.3	15.4	20.5	25.6	30.7	35.7	40.8
#11	10.9	16.5	22.2	27.8	33.5	39.1	44.7
#14	12.5	19.2	26.0	32.8	39.6	46.3	53.1
#18	15.3	24.3	33.3	42.4	51.4	60.4	69.5

*Table Assumptions:

a. Side cover 1.5 in. each side.
b. #3 stirrups for bars #11 and smaller.
c. #4 stirrups for bars #14 and #18.
d. Since stirrups are bent around 4 stirrup bar diameters, the distance from centroid of bar nearest side face of beam to inside face of #3 stirrup is taken as 0.75 in. for bars #11 and smaller; and equal to the bar radius for #14 and #18 bars.

Table 3.9.1 Total Areas for Various Numbers of Reinforcing Bars

BAR SIZE	NOMINAL DIAMETER (in.)	WEIGHT (lb/ft)	1	2	3	4	5	6	7	8	9	10
			NUMBER OF BARS									
#3	0.375	0.376	0.11	0.22	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10
#4	0.500	0.668	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
#5	0.625	1.043	0.31	0.62	0.93	1.24	1.55	1.86	2.17	2.48	2.79	3.10
#6	0.750	1.502	0.44	0.88	1.32	1.76	2.20	2.64	3.08	3.52	3.96	4.40
#7	0.875	2.044	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00
#8	1.000	2.670	0.79	1.58	2.37	3.16	3.95	4.74	5.53	6.32	7.11	7.90
#9	1.128	3.400	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
#10	1.270	4.303	1.27	2.54	3.81	5.08	6.35	7.62	8.89	10.16	11.43	12.70
#11	1.410	5.313	1.56	3.12	4.68	6.24	7.80	9.36	10.92	12.48	14.04	15.60
#14[a]	1.693	7.65	2.25	4.50	6.75	9.00	11.25	13.50	15.75	18.00	20.25	22.50
#18[a]	2.257	13.60	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00	40.00

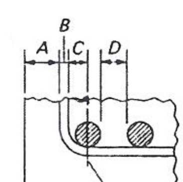
[a] #14 and #18 bars are used primarily as column reinforcement and are rarely used in beams.

$A = 1\frac{1}{2}$-in. clear cover to stirrup

$B = \frac{3}{8}$-in. stirrup bar diameter

$C =$ For #11 and smaller bars, use twice the diameter of #3 stirrups (i.e., $C = 0.75$ in.). For #14 and #18 bars, use $C = 0.5d_b$

$D =$ clear distance between bars $= d_b$ or 1 in., whichever is greater (where d_b is the diameter of the larger adjacent longitudinal bar)



Diameter of corner bar is assumed to be located to intersect the horizontal tangent to stirrup bend

Table A.7 Values of ρ Balanced, ρ to Achieve Various ϵ_t Values, and ρ Minimum for Flexure. All Values Are for Tensilely Reinforced Rectangular Sections

f_y	f'_c	3000 psi $\beta_1 = 0.85$	4000 psi $\beta_1 = 0.85$	5000 psi $\beta_1 = 0.80$	6000 psi $\beta_1 = 0.75$
Grade 40 40,000 psi (275.8 MPa)	ρ balanced	0.0371	0.0495	0.0582	0.0655
	ρ when $\epsilon_t = 0.004$	0.0232	0.0310	0.0364	0.0410
	ρ when $\epsilon_t = 0.005$	0.0203	0.0271	0.0319	0.0359
	ρ when $\epsilon_t = 0.0075$	0.0155	0.0206	0.0243	0.0273
	ρ min for flexure	0.0050	0.0050	0.0053	0.0058
Grade 50 50,000 psi (344.8 MPa)	ρ balanced	0.0275	0.0367	0.0432	0.0486
	ρ when $\epsilon_t = 0.004$	0.0186	0.0248	0.0291	0.0328
	ρ when $\epsilon_t = 0.005$	0.0163	0.0217	0.0255	0.0287
	ρ when $\epsilon_t = 0.0075$	0.0124	0.0165	0.0194	0.0219
	ρ min for flexure	0.0040	0.0040	0.0042	0.0046
Grade 60 60,000 psi (413.7 MPa)	ρ balanced	0.0214	0.0285	0.0335	0.0377
	ρ when $\epsilon_t = 0.004$	0.0155	0.0206	0.0243	0.0273
	ρ when $\epsilon_t = 0.005$	0.0136	0.0181	0.0212	0.0239
	ρ when $\epsilon_t = 0.0075$	0.0103	0.0138	0.0162	0.0182
	ρ min for flexure	0.0033	0.0033	0.0035	0.0039
Grade 75 75,000 psi (517.1 MPa)	ρ balanced	0.0155	0.0207	0.0243	0.0274
	ρ when $\epsilon_t = 0.004$	0.0124	0.0165	0.0194	0.0219
	ρ when $\epsilon_t = 0.005$	0.0108	0.0144	0.0170	0.0191
	ρ when $\epsilon_t = 0.0075$	0.0083	0.0110	0.0130	0.0146
	ρ min for flexure	0.0027	0.0027	0.0028	0.0031

Table A.12 (Continued)

ρ	$\frac{M_u}{\phi bd^2}$	ρ	$\frac{M_u}{\phi bd^2}$	ρ	$\frac{M_u}{\phi bd^2}$	ρ	$\frac{M_u}{\phi bd^2}$
0.0102	538.3	0.0111	578.8	0.0120	618.0	0.0129	656.2
0.0103	542.9	0.0112	582.3	0.0121	622.3	0.0130	660.9
0.0104	547.4	0.0113	587.6	0.0122	626.6	0.0131	664.5
0.0105	551.9	0.0114	592.0	0.0123	630.9	0.0132	668.6
0.0106	556.4	0.0115	596.4	0.0124	635.1	0.0133	672.8
0.0107	560.9	0.0116	600.7	0.0125	639.4	0.0134	676.9
0.0108	565.4	0.0117	605.1	0.0126	643.6	0.0135	681.0
0.0109	569.9	0.0118	609.4	0.0127	647.8	0.0136	685.0
0.0110	574.3	0.0119	613.7	0.0128	652.0		

Table A.13 f_y = 60,000 PSI; f'_c = 4000 PSI—U.S. Customary Units

	ρ	$\frac{M_u}{\phi bd^2}$	ρ	$\frac{M_u}{\phi bd^2}$	ρ	$\frac{M_u}{\phi bd^2}$	ρ	$\frac{M_u}{\phi bd^2}$
ρ_{min} for temp. and shrinkage	0.0018	106.3	0.0041	237.1	0.0064	362.2	0.0087	481.8
	0.0019	112.1	0.0042	242.6	0.0065	367.6	0.0088	486.9
	0.0020	117.1	0.0043	248.2	0.0066	372.9	0.0089	491.9
	0.0021	123.7	0.0044	253.7	0.0067	378.2	0.0090	497.0
	0.0022	129.4	0.0045	259.2	0.0068	383.4	0.0091	502.0
	0.0023	135.2	0.0046	264.8	0.0069	388.7	0.0092	507.1
	0.0024	141.0	0.0047	270.3	0.0070	394.0	0.0093	512.1
	0.0025	146.7	0.0048	275.8	0.0071	399.2	0.0094	517.1
	0.0026	152.4	0.0049	281.2	0.0072	404.5	0.0095	522.1
	0.0027	158.1	0.0050	286.7	0.0073	409.7	0.0096	527.1
	0.0028	163.8	0.0051	292.2	0.0074	414.9	0.0097	532.0
	0.0029	169.5	0.0052	297.6	0.0075	420.1	0.0098	537.0
	0.0030	175.2	0.0053	303.1	0.0076	425.3	0.0099	542.0
	0.0031	180.9	0.0054	308.5	0.0077	430.5	0.0100	546.9
	0.0032	186.6	0.0055	313.9	0.0078	435.7	0.0101	551.8
ρ_{min} for flexure	0.0033	192.2	0.0056	319.3	0.0079	440.9	0.0102	556.7
	0.0034	197.9	0.0057	324.7	0.0080	446.0	0.0103	561.7
	0.0035	203.5	0.0058	330.1	0.0081	451.2	0.0104	566.6
	0.0036	209.1	0.0059	335.5	0.0082	456.3	0.0105	571.5
	0.0037	214.7	0.0060	340.9	0.0083	461.4	0.0106	576.3
	0.0038	220.3	0.0061	346.2	0.0084	466.5	0.0107	581.2
	0.0039	225.9	0.0062	351.6	0.0085	471.6	0.0108	586.1
	0.0040	231.5	0.0063	356.9	0.0086	476.7	0.0109	590.9

Table A.13 (Continued)

ρ	$\frac{M_u}{\phi b d^2}$	ρ	$\frac{M_u}{\phi b d^2}$	ρ	$\frac{M_u}{\phi b d^2}$	ρ	$\frac{M_u}{\phi b d^2}$
0.0110	595.7	0.0128	681.0	0.0146	762.8	0.0164	841.2
0.0111	600.6	0.0129	685.6	0.0147	767.2	0.0165	845.4
0.0112	605.4	0.0130	690.3	0.0148	771.7	0.0166	849.7
0.0113	610.2	0.0131	694.9	0.0149	776.1	0.0167	853.9
0.0114	615.0	0.0132	699.5	0.0150	780.5	0.0168	858.1
0.0115	619.8	0.0133	704.1	0.0151	784.9	0.0169	862.3
0.0116	624.5	0.0134	708.6	0.0152	789.3	0.0170	866.5
0.0117	629.3	0.0135	713.2	0.0153	793.7	0.0171	870.7
0.0118	634.1	0.0136	717.8	0.0154	798.1	0.0172	874.9
0.0119	638.8	0.0137	722.3	0.0155	802.4	0.0173	879.1
0.0120	643.5	0.0138	726.9	0.0156	806.8	0.0174	883.2
0.0121	648.2	0.0139	731.4	0.0157	811.1	0.0175	887.4
0.0122	653.0	0.0140	735.9	0.0158	815.4	0.0176	891.5
0.0123	657.7	0.0141	740.4	0.0159	819.7	0.0177	895.6
0.0124	662.3	0.0142	744.9	0.0160	824.1	0.0178	899.7
0.0125	667.0	0.0143	749.4	0.0161	828.3	0.0179	903.9
0.0126	671.7	0.0144	753.9	0.0162	832.6	0.0180	907.9
0.0127	676.3	0.0145	758.3	0.0163	836.9	0.0181	912.0

Table A.14 Size and Pitch of Spirals, ACI Code—U.S. Customary Units

Diameter of column (in.)	Out to out of spiral (in.)	f'_c			
		2500	3000	4000	5000
f_y = 40,000:					
14, 15	11,12	$\frac{3}{8}$–2	$\frac{3}{8}$–$1\frac{3}{4}$	$\frac{1}{2}$–$2\frac{1}{2}$	$\frac{1}{2}$–$1\frac{3}{4}$
16	13	$\frac{3}{8}$–2	$\frac{3}{8}$–$1\frac{3}{4}$	$\frac{1}{2}$–$2\frac{1}{2}$	$\frac{1}{2}$–2
17–19	14–16	$\frac{3}{8}$–$2\frac{1}{4}$	$\frac{3}{8}$–$1\frac{3}{4}$	$\frac{1}{2}$–$2\frac{1}{2}$	$\frac{1}{2}$–2
20–23	17–20	$\frac{3}{8}$–$2\frac{1}{4}$	$\frac{3}{8}$–$1\frac{3}{4}$	$\frac{1}{2}$–$2\frac{1}{2}$	$\frac{1}{2}$–2
24–30	21–27	$\frac{3}{8}$–$2\frac{1}{4}$	$\frac{3}{8}$–2	$\frac{1}{2}$–$2\frac{1}{2}$	$\frac{1}{2}$–2
f_y = 60,000:					
14, 15	11, 12	$\frac{1}{4}$–$1\frac{3}{4}$	$\frac{3}{8}$–$2\frac{3}{4}$	$\frac{3}{8}$–2	$\frac{1}{2}$–$2\frac{3}{4}$
16–23	13–20	$\frac{1}{4}$–$1\frac{3}{4}$	$\frac{3}{8}$–$2\frac{3}{4}$	$\frac{3}{8}$–2	$\frac{1}{2}$–3
24–29	21–26	$\frac{1}{4}$–$1\frac{3}{4}$	$\frac{3}{8}$–3	$\frac{3}{8}$–$2\frac{1}{4}$	$\frac{1}{2}$–3
30	17	$\frac{1}{4}$–$1\frac{3}{4}$	$\frac{3}{8}$–3	$\frac{3}{8}$–$2\frac{1}{4}$	$\frac{1}{2}$–$3\frac{1}{4}$