14 - Mar 1 Lecture

- Upper and lower triangular square matrices
- Finding the determinant of an upper or lower triangular matrix
- Relationship between the determinant and row reduction
- Common mistakes regarding determinants

Determinants Pt.2 "less error-prone method"

Upper Triangular	A nxn matrix A is called upper triangular if Ai, j = 0 for all i>j.
Lower Triangular	A nxn matrix B is called lower triangular if Ais = 0 for all i <j.< th=""></j.<>
Ex:	$A = \begin{array}{ccccccccccccccccccccccccccccccccccc$
	A = 0 4 5 is upper triangular
Ex:	$B = \begin{bmatrix} 1 & 0 & 0 \\ 2 & 0 & 0 \\ 3 & 4 & 5 \end{bmatrix}$ is lower triangular
	B= 2 0 0 is lower triangular
Ex:	atrix 0 0 0 is both upper and lower triangular
~	atrix 0 0 0 is both upper and lower triangular
ev.	
E×:	0 2 0 is both upper and lower triangular
	15 both upper and 10 was triangular
Ev	What is Det(A)?
	$A = \begin{bmatrix} 2 & 3 & 1 & 4 & 7 \\ 0 & 2 & \pi & \sqrt{2} & -12 \\ 0 & 0 & 1 & 7 & 18 \\ 0 & 0 & 0 & -3 & 22 \end{bmatrix}$ $Det(A) = (-1)^{1+1}(2) Det\begin{bmatrix} 2 & \pi & \sqrt{2} & -12 \\ 0 & 1 & 7 & 18 \\ 0 & 0 & -3 & 22 \\ 0 & 0 & 0 & -3 \end{bmatrix} + 0 + 0 + 0 + 0$
	A = 0 0 1 7 18
	Det (A) = (-1) (2) Det + 0 + 0 + 0 + 0
	0 0 0 0 -3
	Let i=1 [1718]
	Let $j=1$ $= (2) \left((-1)^{2} (2) \text{ Det } \begin{bmatrix} 1 & 7 & 18 \\ 0 & -3 & 2^{2} \\ 0 & 0 & -3 \end{bmatrix} + 0 + 0 + 0 \right)$
	0 0 - 3
	$= (2)(2)(1)^{2}(1) 21 = [-3 22] + 0 + 0$
	$= (2)(2)\left((-1)^{2}(1) \text{ Det } \begin{bmatrix} -3 & 22\\ 0 & -3 \end{bmatrix} + 0 + 0\right)$
	= (2)(2)(1)[(-3)(-3) - (22)(0)]
	= (2)(2)(1)(-3)(-3) multiply terms on the diagonal
	= 36

Determinant of Upper or	The d	eteri	minant	of an	upper or 1	ower 7	fiiangular mat	rix is	the
Lower Triangular Matrix					es on the				
							•		
	Det (A) = [Π Α .,: ·	- A _{1,1} · .	equivalent of E				
		i =	1						
Relationship between	Ex: If A	~ B	R31 = 2P	3 then De	t(B) = 2 Det(A))			
Row Reduction and the									
determinant	Why?	\ _	n it.	ر ز	at (Acc. s)				
	Det LA	، = (:ز	2 (-1) = 1	Αίι; <u>ν</u>	et (A(i,j)) unchanged				
		1	unchanged	doubled	•				
general formula	A ~ C	Ri=	s R i	Det (c)	= s Det A	dou bl	now - det double	2 5	
	A ~ D	Ri = 1	2 i - s Rj	Det (D)	= Det (A)	repl-	operation -> det unch	anged	
		mak	e sure you! scaling Ri	re					
		not	scaling Ri						
	A~E	$R_i \longleftrightarrow$	R _j	Det (E)	= - Det (A)	row i	nterchange nega	tes Det.	
	odd #	interc	hanges —	negate de	f				
	even #	interc	hanges ->	same det					
	All REF	squ	are matr	ices are	upper triangula	ar.			
Ex:	What is								
	['	2 -2		1 2 -2]				
	A = -3	-6 3	~ B ₁ =	0 0 -3	$R_{2}^{1} = R_{2} + 3R_{1}$ $R_{3}^{1} = R_{3} - 2R_{1}$				
	[2	7 2	J	0 3 6	R3'= R3-2 R1				
				1 2 -2					
			~ B2 =	0 0 -3					
				0 1 2	$R_3' = \frac{1}{3} R_3$				
				1 2 -2					
			~ B3 =	0 1 2	$R_2 \longleftrightarrow R_3$				
				[0 0 -3					
) = (1)(1)(
					$(B_2) \Rightarrow Det (B_2)$				
					$+ (B_1) \Rightarrow Det (B_1)$	= 9			
			Det (A)	= Det (B ₁)	= [9]				

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from tutorial 3
                            Find det.

\begin{bmatrix}
3 & -2 & 0 \\
-1 & 1 & 1 \\
1 & 0 & 2
\end{bmatrix}

= 3 \text{ Det}
\begin{bmatrix}
1 & -2/3 & 0 \\
-1 & 1 & 1 \\
1 & 0 & 2
\end{bmatrix}

R_1' = \frac{1}{3}R_1

                       Ex: Find det.
                                               = 3 \text{ Det} \begin{bmatrix} 1 & -^{2}/3 & 0 \\ 0 & ^{1}/3 & 1 \\ 0 & ^{2}/3 & 2 \end{bmatrix} R_{2}^{1} = R_{2} + R_{1}
                                       Transpose [1 -2/3 0]
                                            = 3. 1/3 Det 0 3 3 R2 = 3 R2
                     can do during now
                   reduction. usually not helpful though
                                                          [1 - \frac{2}{3} 0]
                                                  = Det 0 1 3
                                                          \begin{bmatrix} 0 & 0 & 0 \end{bmatrix} R_3^1 = R_3^{-2}/3 R_2
                                                   = (1)(1)(0)
                                                   = 0
                             In general, lecture 13's method works better for 3 x 3 matrices.
                             This method is better for matrices 5x5 or bigger.
                              4×4 wl lots of zeroes -> lecture 13
                              4x4 wlo zeroes -> lecture 14 method
                              Property 1 Det (A) \neq 0 if and only if A is invertible
                              Property 2 Det (A) = Det (AT) (If you want to do column reductions instead of
                              Property 3 Det (AB) = Det(A) Det(B) row reductions)
                               4 A or B not invertible → Det (AB) = 0
                              Det (A^{-1}) = \frac{1}{Det(A)}.
                                                                                -> why?
                              Det (A^k) = (Det(A))^k \leftarrow k is integer
                                                                                 A A-1 = In
                              Ex: Det(A^2) = (Det(A))^2
                             Det(2A) = 2^{n} Det(A) (A is n \times n)
    Most common mistake
                              If A is n \times n then Det(cA) = c^n Det(A) NOT c Det(A)
                                              no formula, Det (A + B) has
                             Det (A+B) = no relationship to Det (A) and Det (B)
Another common mistake
                                              NOT Det(A) + Det(B)
                              Need to sum A and B into one matrix, then calculate it
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Can combine row reduction with def formula	Find determinant of matrix. (from end of lecture 13) $ \begin{bmatrix} 1 & 3 & 2 & 0 \\ 4 & 1 & 3 & 1 \\ -1 & -5 & 2 & 2 \\ 2 & 3 & 1 & 4 \end{bmatrix} = Det \begin{bmatrix} 1 & 3 & 2 & 0 \\ 0 & -11 & -5 & 1 \\ 0 & -2 & 4 & 2 \\ 0 & -3 & -3 & 4 \end{bmatrix} \begin{bmatrix} R_2' = R_2 - 4R_1 \\ R_3' = R_3 + R_1 \\ R_4' = R_4 - 2R_1 \end{bmatrix} $ Let $j = 1$. $ \begin{bmatrix} -11 & -5 & 1 \\ -2 & 4 & 2 \\ -3 & -3 & 4 \end{bmatrix} + 0 + 0 + 0 $ $ \begin{bmatrix} -11 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} \begin{bmatrix} R_2' = R_2 - 2R_1 \\ R_3' = R_3 - 4R_1 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -1+3 \\ -(-1) & (1) & Det \end{bmatrix} \begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ $ \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix} $ Let $j = 3$ Let j	
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Let $j=1$.	Let $j=1$. $= (-1)^{1+1}(1) \text{ Det } \begin{bmatrix} -11 & -5 & 1 \\ -2 & 4 & 2 \\ -3 & -3 & 4 \end{bmatrix} + 0 + 0 + 0$ $= \text{ Det } \begin{bmatrix} -11 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} R_2^1 = R_2 - 2R_1$ $= (-1) \begin{bmatrix} 11 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 \end{bmatrix} + 0 + 0$ $= \begin{bmatrix} -234 \\ 12 & 14 \\ 13 & 14 \end{bmatrix} + 0 + 0$ $= \begin{bmatrix} -234 \\ 14 & 17 \end{bmatrix}$ Let $5 \times 5 = -702$ (So much quicker to do than formula from lecture 13)	
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Let $j=1$. $= (-1)^{1+1}(1) \text{ Det } \begin{bmatrix} -11 & -5 & 1 \\ -2 & 4 & 2 \\ -3 & -3 & 4 \end{bmatrix} + 0 + 0 + 0$ $= \text{ Det } \begin{bmatrix} -11 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} R_2^1 = R_2 - 2R_1$ $= (-1) \begin{bmatrix} 11 & 17 & 17 \\ 11 & 17 & 17 \end{bmatrix} + 0 + 0$ $= \begin{bmatrix} -234 \\ 12 & 17 \\ 13 & 17 \end{bmatrix} + 0 + 0$ $= \begin{bmatrix} -234 \\ 14 & 17 \end{bmatrix}$ Let $5 \times 5 = -702$ (So much quicker to do than formula from lecture 13)	Let $j=2$.	-1 -5 2 2 - pet 0 -2 4 2 R3' = R3 + R1
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2 R_1 $ $ = \begin{bmatrix} 1+3 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} R_3^1 = R_3 - 4 R_1 $ $ = \begin{bmatrix} 1+3 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} $ $ = \begin{bmatrix} 1+3 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} $ $ = \begin{bmatrix} 1+3 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ 2 & 14 \end{bmatrix} +$	Let j= 1.
$\begin{bmatrix} -1 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} R_{2}^{1} = R_{2} - 2R_{1}$ $= \begin{bmatrix} 1 & 1 & 1 \\ 41 & 17 & 0 \end{bmatrix} R_{3}^{1} = R_{3} - 4R_{1}$ Let $j = 3$ $= \begin{bmatrix} 1+3 \\ -(-1) & (1) \end{bmatrix} Det \begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0$ $= \begin{bmatrix} -234 \\ 41 & 17 \end{bmatrix}$ $\Rightarrow Det 5 \times 5 = -702 (S0 much quicker to do than formula from lecture 13)$	$\begin{bmatrix} -1 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} R_2! = R_2 - 2R_1$ $= (-1) (1) Det \begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0$ $= \begin{bmatrix} -234 \\ 14 \end{bmatrix}$ $\Rightarrow Det 5 \times 5 = -702 (S0 \text{ much quicker to do than formula from lecture } 13)$	[-11 -s 1]
$ \begin{bmatrix} -11 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} R_2^1 = R_2 - 2R_1 $ $ = R_3^1 = R_3 - 4R_1 $ Let $j = 3$ $ = (-1)^{1+3} (1) \text{ Det } \begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = -234$ $ \Rightarrow \text{ Det } 5 \times 5 = -702 \text{(So much quicker to do than formula from lecture 13)} $	$ \begin{bmatrix} -11 & -5 & 1 \\ 20 & 14 & 0 \\ 41 & 17 & 0 \end{bmatrix} R_{2}! = R_{2} - 2R_{1} $ $ = \begin{bmatrix} 1+3 \\ (-1) & (1) \end{bmatrix} Det \begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0 $ $ = \begin{bmatrix} -234 \\ -234 \end{bmatrix} $ $ Det 5 \times 5 = -702 $ (So much quicker to do than formula from lecture 13)	= (-1) ¹⁺¹ (1) Det -2
Let $j=3$ = (-1) (1) Det $\begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix}$ + 0 + 0 = $\begin{bmatrix} -234 \end{bmatrix}$ b) Det $5 \times 5 = -702$ (SO much quicker to do than formula from lecture 13)	Let $j=3$ = (-1) (1) Det $\begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix}$ + 0 + 0 = $\begin{bmatrix} -234 \end{bmatrix}$ b) Det $5 \times 5 = -702$ (SO much quicker to do than formula from lecture 13)	[-3 -3 4]
Let $j=3$ = (-1) (1) Det $\begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix}$ + 0 + 0 = $\begin{bmatrix} -234 \end{bmatrix}$ Ly Det $5 \times 5 = -702$ (So much quicker to do than formula from lecture 13)	Let $j=3$ = (-1) (1) Det $\begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix}$ + 0 + 0 = $\begin{bmatrix} -234 \end{bmatrix}$ Ly Det $5 \times 5 = -702$ (SO much quicker to do than formula from lecture 13)	[-II -5]
Let $j=3$ $= (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)$	Let $j=3$ $= (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)$	= Det 20 14 0 R21=R2-2R1
$= (-1) (1) \text{ Det } \begin{bmatrix} 20 & 14 \\ 41 & 17 \end{bmatrix} + 0 + 0$ $= \frac{-234}{41}$ Le Det $5 \times 5 = -702$ (So much quicker to do than formula from lecture 13)	$= (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = (-1)^{1+3} = ($	41 17 0 R31 = R3 - 4R1
= -234 1-234 1-234 1-234 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1-305 1	= -234 1-> Det 5×5 = -702 (SO much quicker to do than formula from lecture 13)	Let j=3
= -234 1-> Det 5×5 = -702 (SO much quicker to do than formula from lecture 13)	= -234 1-> Det 5×5 = -702 (So much quicker to do than formula from lecture 13)	1+3 -(1) (1) Dat [20 14]
4) Det 5×5 = -702 (SO much quicker to do than formula from lecture 13)	13 Det 5×5 = -702 (So much quicker to do than formula from lecture 13)	41 17
		= -234
		13 Det 5×5 = -702 (SO much quicker to do than formula from lecture 13)
		(Least error-prone method)