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	The state of the s
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29	$A = \begin{cases} 1 & 2 & \cdots & n \\ n+1 & n+2 & 2n \end{cases} - R_2 \sim R_2 - (n+1) R_1 $
9	
- L	R3 ~ R3-(2n+1) R21
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ACM/IDS 104 - Problem Set 1 - MATLAB Problems

Before writing your MATLAB code, it is always good practice to get rid of any leftover variables and figures from previous scripts.

```
clc; clear; close all;
```

NOTE: As this is the first problem set (and many of you might be unfamiliar with MATLAB) we will provide some helper code. As the term progresses (and you become more experienced) we will omit this.

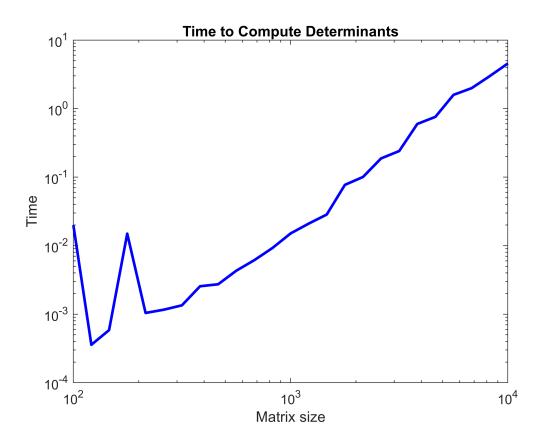
Problem 6 (10 points) Determinants are Expensive to Compute

In lecture 2, we discussed that computing determinants is a computationally expensive task. Let's see how long it takes MATLAB to compute determinants of large matrices (MATLAB uses LU factorization, not the Leibniz formula of course). To do this, we will:

- 1. Generate 25 values of *n* logarithmically spaced between 10^2 and 10^4 .
- 2. For each n, generate a matrix A of size $n \times n$, with entries a_{ij} being sampled from the standard normal distribution. Use randn().
- 3. Compute det(A) and measure the time MATLAB took to complete the computatation. Use det(), tic and toc.
- 4. Plot the times versus the values of n in the log-log scale. Label the axes and give a meaningful plot title.

```
% Setup is completed for you; make sure you understand what is happening
vals = 25:
n_vals = floor(logspace(2, 4, vals));
times = NaN(vals, 1);
% TODO
for i = 1 : vals
    % Define n as the i-th element of the n vals array
    n = n_vals(i);
    % Create the matrix A as described in step 2
    A = randn(n, n);
    tic; % This tells MATLAB to start the timer
    % Compute the determinant of A
    det(A);
    times(i) = toc; % This tells MATLAB to stop the timer and store the time
end
%{
PLOTTING
Here is an elementary example of how to plot in MATLAB. Feel free
```

```
to explore and customize your plots to make them more attractive!
%}
figure; % Always tell MATLAB you are starting a new figure
loglog(n_vals, times, "b", "LineWidth", 2); % log-log scale plot
xlabel("Matrix size");
ylabel("Time");
title("Time to Compute Determinants");
```



Problem 7 (10 points) Solving Linear Systems

We have the matrix:

$$B = \begin{pmatrix} 1 & 2 & \cdots & n \\ n+1 & n+2 & \cdots & 2n \\ \vdots & \vdots & & \vdots \\ n^2 - n+1 & n^2 - n+2 & \cdots & n^2 \end{pmatrix}$$

Part (a) (5 points)

In this part, your task is to find rank(B). As mentioned in the problem set, MATLAB is not needed to obtain the answer. However, we can use MATLAB to make a right guess and check our answer. To do this, we first need to construct matrix B in MATLAB:

NOTE: Although you can check your answer here, you still need to justify and show your reasoning to obtain full credit:)

```
n = 100; % set n as specified in Part (b)
B = 1 : n;
for i = 2 : n
          B(i,:) = B(i-1,:) + n;
end
r = rank(B) % check your answer here
```

r = 2

Part (b) (5 points)

Set n = 100 and consider the system of linear equations Bx = c where $c = (1 \ 2 \ \cdots \ n)^T$. Find a solution x such that its first [n - rank(B)] components are zero. What are the non-zero components of x?

HINT: The backslash operator $B \setminus c$ issues a warning if B is nearly singular and raises an error condition if it detects exact singularity. In that case, use pinv(B)*c for finding a particular solution of Bx = c. The function pinv(B) returns the "pseudoinverse" of B (will discuss the Moore-Penrose pseudoinverse in lecture 16). Also, the following built-in function may be useful: null.

```
%{
Let us start by defining the column vector c as specified above.
Remember that in MATLAB we can use ' to transpose a vector.
%}
c = (1:n)';
%{
Now, we obtain a particular solution, x_0, as described above
%}
x_0 = pinv(B)*c;
%{
Use null(B) to define the matrix V, whose columns form an orthonormal
basis in the vector space of all solution of the homogeneous
system Bx=0.
%}
V = null(B);
%{
Use the rank, r, found in part (a) to define k = n - rank(B).
This is the number of free variables / dimension of the vector
space.
%}
k = n - r;
```

This is a good point to review what we have done so far. Recall that the desired solution of the system is:

$$x = x_0 + V\alpha$$
 (*)

where α is a $k \times 1$ vector. We can obtain α by solving the system:

```
x_0 + V\alpha = 0 \quad (\star \star)
```

```
%{
Find alpha by solving the described system (**).
-> Hint1: Remeber that alpha is a k*1 vector. Hence, you need to
restrict the sizes of x_0 and V
                 -> Hint2: Use backslash
%}
%x_0_{\text{restricted}} = x_0(1:k);
%V_restricted = V(1:k,:)
%neg_x_0_restricted = -1 * x_0_restricted
%alpha = V_restricted\neg_x_0_restricted
alpha = V(1:k,:) -x_0(1:k);
%{
Finally, put everything together and find x using (*)
Use disp(x) to display your solution.
%}
x = x 0 + V * alpha;
disp(x)
```

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- -0.0000
- -0.0000
- -0.0000
- 0.0000 -0.0000
- -0.0000
- -0.0000
- 0.0000
- -0.0000
- 0.0000
- 0.0000
- 0.0000
- 0.0000
- -0.0000
- 0.0000
- -0.0000 0.0000
- 0.0000
- -0.0000
- 0.0000
- 0.0000
- -0.0000
- -0.0000

```
The second to last entry of x is
   0.0000
                    2.49 * 10^-14 which is 10^4
   -0.0000
                   times greater than the other
   -0.0000
                    entries, so we can consider it
   0.0000
                    non-zero relatively.
   0.0100
%{
Now, let us see how x compares to the actual solution.
Un-comment the following 2 lines of code once you reach this part.
%}
error = norm(B*x - c);
disp(error);
```

Don't forget to report the non-zero components of *x*!

0.0000

4.1439e-12