I pledge to support the Honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism. I am aware that as a member of the academic community, it is my responsibility to turn in all suspected violators of the Honor Code. I will report to a hearing if summoned.

Student Signature: ___________________________________________________

Student Name (BLOCK CAPITALS): ___________________________________

UIN Number: _________________________________________________

Please turn in this examination document with the pledge above signed and with one answer book for each solved problem.

1. This examination contains 26 problems from the following six areas:
   A. MATH (At most 3 problems can be answered from the Math area) A1 A2 A3 A4
   B. CIRCUITS & ELECTRONICS B1 B2 B3
   C. SYSTEMS, SIGNAL AND IMAGE PROCESSING C1 C2 C3 C4 C5 C6
   D. PHYSICAL ELECTRONICS I D1 D2 D3 D4
   E. PHYSICAL ELECTRONICS II E1 E2 E3
   F. COMPUTER SYSTEMS F1 F2 F3 F4 F5 F6

2. You must answer Eight problems, but no more than three from the MATH group.
3. Answer in the blue books provided. Use a separate book for each problem. Put the title and problem number on the front of each book (eg., MATH A-1)
4. Return all the 26 problems.
5. You will be graded on your answers to Eight problems only.
6. The examination is “closed-book;” only blue books, exam problems and a scientific calculator are allowed. No formula sheet is allowed. Some problems include reference formulas. No material shall be shared without prior permission of the proctor(s).
7. You have four hours to complete this examination.
In a resistor-inductor circuit, the power source has a voltage dependence $E=E_m\sin(\omega t)$, where $E_m$ and $\omega$ are constant. $R$ and $L$ are also constant. After the switch (SW) is turned on, what is the time-dependent expression for the current $i(t)$? Assuming the current is zero before the switch is turned on, i.e., $i(t=0)=0$.

Hint: You solve the current equation: $\frac{di}{dt} + R \frac{i}{L} = \frac{E}{L}$
PROBLEM A2 – MATH

Vector Calculus

Consider an infinitely long, thin wire running along the x-axis in 3D space. If an electric current $I$ passes through the wire, it induces a magnetic field $B$ that is a function of space:

$$B(r) = \frac{\mu_0 I}{2\pi|r|}\hat{r} \times \hat{e}_x,$$

where $\mu_0 = 4\pi \cdot 10^{-7}\, T\cdot m$ is the vacuum permeability and $\hat{e}_x$ is the unit vector in x-direction.

a) Sketch $B(r)$ in the yz-plane.

b) Compute the contour integral of $B$ over the circle $y^2 + z^2 = 1\, m^2$ in counter-clockwise direction.

c) Compute $\text{curl}(B)$. 
PROBLEM A3 – MATH

Linear Algebra

Consider two real-valued N-dimensional column vectors \( \bar{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_N \end{bmatrix} \) and \( \bar{y} = \begin{bmatrix} y_1 \\ \vdots \\ y_N \end{bmatrix} \).

1. Write the expression for the dot product \( \bar{x} \cdot \bar{y} \) (also referred to as the inner product) of the two vectors.
2. Define the Euclidian norm for vector \( \| \bar{x} \| \) and write it in terms of the dot product.
3. Write the expression of the distance between the two vectors \( \bar{x} \) and \( \bar{y} \).
4. Write the expression for the cosine of the angle \( \theta \) between two vectors \( \bar{x} \) and \( \bar{y} \).
5. Consider now a matrix with dimensions \( m \times n : A = [a_{ij}], 1 \leq i \leq m, 1 \leq j \leq n \). Define the norm-2 for matrix \( A \) and show that \( \| A \|_2 \) is equal to the maximum singular value of the matrix \( A \).
PROBLEM A4 – MATH

Probability

(1). Let $X$ and $Y$ be continuous random variables with JPDF: $f_{XY}(x,y) = c$ for $0 \leq x \leq y \leq 1$, where “c” is a constant. Determine: $f_X(x)$ and $P[X \leq 0.5]$.

(2). Find the PDF of $W = X + Y$ when $X$ and $Y$ have the joint PDF:

$$f_{X,Y}(x,y) = 2, \quad \text{for} \quad 0 \leq x \leq y \leq 1; \quad \text{and} \quad f_{X,Y}(x,y) = 0 \text{ otherwise}.$$
Circuits

Sinusoidal Steady State Power

The load impedance $Z_L$ for the circuit shown in the figure is adjusted until maximum average power is delivered to $Z_L$.

a) Find the maximum average power delivered to $Z_L$.

b) What percentage of the total power developed in the circuit is delivered to $Z_L$?
The op amp shown in the circuit is ideal. There is no energy stored in the circuit at the time it is energized. If $v_g = 16,000 \ u(t) \ V$, find

a. Find $V_s(s)$.
b. Find $v_o(t)$.
c. How long does it take to saturate the operational amplifier?
d. How small the rate of increase in $v_g$ must be to prevent saturation?

PROBLEM B2 – CIRCUITS AND ELECTRONICS

Circuits
Laplace Application to Circuit Analysis

If $v_g = 16,000 \ u(t) \ V$, find

- a. Find $V_s(s)$.
- b. Find $v_o(t)$.
- c. How long does it take to saturate the operational amplifier?
- d. How small the rate of increase in $v_g$ must be to prevent saturation?
For the PMOS transistor in the circuit with $\mu C=8 \mu A/V^2$, W/L=25, and $|V_{tp}|=1V$, the circuit operates with $R=30k\Omega$ for $I=100\mu A$.

(a) Does PMOS transistor operate in saturation or triode mode? Explain why?

(b) Calculate the voltages of $V_{SD}$ and $V_{SG}$
PROBLEM C1 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Image Processing

\[
\begin{array}{cccccc}
0 & 1 & 5 & 3 & 7 \\
1 & 2 & 6 & 0 & 5 \\
9 & 1 & 0 & 5 & 4 \\
2 & 2 & 8 & 6 & 5 \\
7 & 6 & 2 & 2 & 9 \\
\end{array}
\]

Given the above 5 X 5 grayscale digital image \( f(x,y) \) and the incomplete 3 X 3 digital filter mask \( h(x,y) \), answer the following questions.

a) Given a fixed-bit representation, determine the minimum number of bits per pixel required to represent the image intensities in \( f(x,y) \). Based on this value, also determine the number of fixed bits required for storing \( f(x,y) \). (4 pts)

b) Determine \( F(0,0) \), where \( F(u,v) \) is the centered 5 X 5 two-dimensional Discrete Fourier Transform (DFT) of \( f(x,y) \). (4 pts)

c) Determine \( h(0,0) \) and \( H(0,0) \) such that the average intensity of the filtered image will not change, neglecting boundary effects. \( H(u,v) \) represents the centered 3 X 3 DFT of \( h(x,y) \). (4 pts)

d) Fill in the empty pixel intensities that result when \( f(x,y) \) is filtered using \( h(x,y) \) determined in (c). State any assumptions. (4 pts)

\[
\begin{array}{cccc}
X & X & X \\
X & X & X \\
X & X & X \\
X & X & X & X \\
X & X & X & X & X \\
\end{array}
\]

e) Sketch and clearly label the histogram that results from applying the following intensity transform below to \( f(x,y) \). (4 pts)

\[
g(x, y) = \begin{cases} 
0 & \text{if } f(x, y) = 2 \\
 f(x, y) - 1 & \text{if } f(x, y) \geq 5 \\
 f(x, y) & \text{otherwise}
\end{cases}
\]
Digital Signal Processing

A causal LTI system is characterized by the following difference equation:

\[ y[n+2] - \frac{5}{6} y[n+1] + \frac{1}{6} y[n] = x[n+2] \]

(a). Determine the system function \( H(z) \) for the system (3 points)
(b). Determine the impulse response \( h[n] \) for the LTI system (3 points).
(c). If \( x[n] = (1/4)^n u[n] \), what is \( y[n] \) (4 points)?
Digital Signal Processing

(a). If the discrete-time signal $x[n]$ is down-sampled by 4, what is the cutoff frequency for the ideal low pass filter to avoid aliasing? (3 points)

(b). If the discrete-time signal $x[n]$ is up-sampled by 2, what is the cutoff frequency for the ideal low pass interpolation filter? (3 points)

(c). Let $X(e^{j\omega})$ denote the Fourier transform of the signal

\[ x[n] = u[n] - u[n-111] \]

What are the values of $X(e^{j\omega})\big|_{\omega=0}$ and $X(e^{j\omega})\big|_{\omega=\pi}$? (4 points)
Control Systems

Problem. Consider the block diagram of an antenna azimuth position control system depicted in the figure below.

(i) Find a proportional or PD controller \( G_c(s) \) so that the closed-loop system meets the following specification: Settling time \( \leq 0.5 \) sec. Your solution should include at least an approximate root locus sketch.

(ii) If \( \theta_i(s) = \frac{1}{s} \), what is the steady-state error for your designed closed-loop system? The error in the time domain is \( e(t) = \theta_i(t) - \theta_o(t) \).

REVIEW

For a prototype second order open-loop transfer function \( G(s) = \frac{\omega_n^2}{s^2 + 2\zeta \omega_n s + \omega_n^2} \) the following unit step response relations are useful:

- percent overshoot = \( 100 \exp(-\zeta / \sqrt{1 - \zeta^2}) \)
- 2% settling time = \( 4 / (\zeta \omega_n) \)

If the loop gain of a closed-loop system can be written as follows:

\[
K_c G(s) = K_c \frac{\prod_{i=1}^{m}(s-z_i)}{\prod_{j=1}^{n}(s-p_j)}
\]

where \( K_c \) is the gain of the controller that needs to be determined and \( G(s) \) represents the transfer function of the plant and the designed portion of the controller with \( m \) zeros at \( z_i \) and \( n \) poles at \( p_j \), then the magnitude condition of root locus is:

\[
|K_c| = \frac{n}{\prod_{j=1}^{n}|s-p_j|}, \quad \text{if } s \text{ a closed-loop pole}
\]

\[
K_c = \frac{m}{\prod_{i=1}^{m}|s-z_i|}
\]

\[
K_c = \frac{\prod_{i=1}^{m}|s-z_i|}{\prod_{j=1}^{n}|s-p_j|}
\]
Communication systems

Consider the message signal \( m(t) = a \cos(2\pi f_m t) \) that is used to modulate the carrier signal \( c(t) = A_c \cos(2\pi f_c t) \), where \( f_c >> f_m \).

1. Write the expression of the modulated signal \( u(t) \) corresponding to double sideband suppressed carrier amplitude modulation (DSB-SC AM) scheme and identify the lower and upper sideband components of \( u(t) \). Argue whether DSB-SC AM is a linear modulation scheme or not.

2. Write the expressions of the pre-envelope signal \( u_o(t) \) and of the complex envelope \( \tilde{u}(t) \) for the DSB-SC AM signal \( u(t) \), and determine its corresponding in-phase and quadrature components \( u_i(t) \) and \( u_Q(t) \).

3. Describe how frequency modulation (FM) of the carrier \( c(t) \) with \( m(t) \) is accomplished and write the mathematical expression of the resulting FM signal \( u(t) \). Argue whether FM is a linear modulation scheme or not.

4. For the FM signal in Part 3 write the expression of the maximum frequency deviation \( \Delta f_{\text{max}} \) and define the modulation index \( \beta_f \) for the FM scheme.

5. Write the expressions of the pre-envelope signal \( u_o(t) \) and of the complex envelope \( \tilde{u}(t) \) for the FM signal \( u(t) \), and determine its corresponding in-phase and quadrature components \( u_i(t) \) and \( u_Q(t) \).

USEFUL TRIONOMETRIC IDENTITIES

\[
\cos(x) \cos(y) = \frac{\cos(x - y) + \cos(x + y)}{2}
\]

\[
\sin(x) \sin(y) = \frac{\cos(x - y) - \cos(x + y)}{2}
\]

\[
\sin(x) \cos(y) = \frac{\sin(x - y) + \sin(x + y)}{2}
\]

\[
\cos(x) = \frac{e^{ix} + e^{-ix}}{2}
\]

\[
\sin(x) = \frac{e^{ix} - e^{-ix}}{2j}
\]
Communication Networks

1. (7 points) Figure (a) shows a subnet. The four columns of figure (b) show the delay vectors received from the neighbors of router J as well as the estimated delays from J to its four neighbors. Please compute the new routing table for J using the Distance Vector Routing protocol.

2. (3 points) For a channel with 10 MHz bandwidth, if the signal to noise ratio is 20 dB, what is the maximum data rate that can be achieved on this channel?
PROBLEM D1 – PHYSICAL ELECTRONICS I

Electromagnetics

(1). The E-field measured in air just above a glass plate is equal to 2 V/m in magnitude and is directed at 45° away from the boundary. The magnitude of the E-field measured just below the boundary is equal to 3 V/m. Find the angle θ for the E-field in the glass just below the boundary.

(2). The H-field in air just above a perfect conductor is given by: \( \mathbf{H} = 3 \mathbf{a}_x + 4 \mathbf{a}_z \) Amps/m. Find the surface current \( \mathbf{J}_s \) on the surface of the perfect conductor, given that the conductor occupies the space \( y < 0 \).
PROBLEM D2 – PHYSICAL ELECTRONICS I

Electromagnetics

Assume that a long cylindrical electron beam moving in air has a charge density of $\rho$ coulombs per meter. The radius of the beam is $a$ and the charge is distributed uniformly as below. (Assume that the beam is infinitely long)

Calculate electric field as function of radius $r$?

$E = \quad (r \leq a)$

$E = \quad (r > a)$
Lasers

1) Write the rate equation for each energy level of the three-level laser below.

\[ \begin{align*}
N_2 & \quad \text{E}_2 \\
N_1 & \quad \text{E}_1 \\
N_0 & \quad \text{E}_0
\end{align*} \]

Assume: The only processes are radiant processes (spontaneous and stimulated), the incident light is monochromatic, and no significant sustained stimulated occurs between the pump level and the upper lasing level.

\[ E_2 - E_0 = h\nu_p, \quad E_1 - E_0 = h\nu \]

Define: \( B_{nm} \) is the Einstein \( B \) coefficient for the \( E_n, E_m \) transitions (e.g., \( B_{10} \) is the Einstein \( B \) coefficient for the \( E_0, E_1 \) transition). Also, note that \( B_{nm} = B_{mn} \).

\( A_{nm} \) is the Einstein \( A \) coefficient for the \( E_n, E_m \) transitions.

\( N_0, N_1, \) and \( N_2 \) population density for \( E_0, E_1, \) and \( E_2 \) energy levels, respectively.

\( g(\nu_p) \) is the line shape function of the incident pump light at \( \nu_p \).

\( g(\nu) \) is the line shape function of the laser light inside the cavity \( \nu \).

\( I_p \) is the irradiance of the incident pump light.

\( I \) is the irradiance of the stimulated emission light between \( E_1, \) and \( E_0. \)

\( c \) is the speed of light.
Mass of electron = 9.10938\times10^{-31} \text{ kg}
Mass of hydrogen atom = 1.67372\times10^{-27} \text{ kg}
Charge of electron = -1.6021766\times10^{-19} \text{ Coulombs}
Avogadro's number = 6.022141\times10^{23}
Boltzmann's constant = 1.38063\times10^{-23} \text{ J/K}

Gas constant = 8.3145 \text{ J/(mol K)}
Planck's constant = 6.62607\times10^{-34} \text{ Js}
Permittivity of free space = 8.854\times10^{-12} \text{ F/m}
Permeability of free space = 1.257\times10^{-6} \text{ H/m}
Velocity of light in free space = 3\times10^8 \text{ m/s}

1 \text{ atm} = 760 \text{ torr} = 1.013 \times10^5 \text{ N/m}^2; \ 1 \text{ Å} = 10^{-10} \text{ cm}

eV = \text{ electron volt} \quad 1.6 \times 10^{-19} \text{ J}
1 \text{ eV of temperature KT} = 11,600^\circ \text{K}

\[ \int_x^\infty e^{-x^2} \, dx = \frac{\pi^{1/2}}{2} \]

\[ \int_x^\infty x^{\frac{1}{2}} e^{-x} \, dx = \frac{(\pi/a)^{1/2}}{2a} \]

\[ \int_x^\infty x^n e^{-x^2} \, dx = \begin{cases} 
\frac{(1)(3)(5) \ldots (n-1)}{2(2a)^{n+1}} (\frac{x}{a})^{1/2} & \text{for even } n \\
\frac{[(n-1)/2]!}{2^{n+1}a^{n+1}} & \text{for odd } n \geq 1
\end{cases} \]

\[ \int_x^\infty x^n e^{-x^n} \, dx = \begin{cases} 
2 \int_0^\infty x^n e^{-x^n} \, dx & \text{for even } n \\
0 & \text{for odd } n
\end{cases} \]

\[ \frac{2}{\pi^{1/2}} \int_x^\infty e^{-x^2} \, dx = \text{erf}(x) \]
PROBLEM D4 – PHYSICAL ELECTRONICS I

Optical Fiber Communications

When a current pulse is applied to a laser diode, the injected carrier pair density \( n \) within the recombination region of width \( d \) changes with time according to the relationship

\[
\frac{\partial n}{\partial t} = \frac{J}{qd} - \frac{n}{\tau}
\]

Assume \( \tau \) is the average carrier lifetime in the recombination region when the injected carrier pair density is \( n_{th} \) near the threshold current \( J_{th} \). That is, in the steady state we have \( \frac{\partial n}{\partial t} = 0 \) so that \( n_{th} = \frac{\tau J_{th}}{qd} \).

If a current pulse of amplitude \( I_p \) is applied to an unbiased laser diode, show that the time needed for the onset of stimulated emission is,

\[
t_d = \tau \ln \frac{I_p}{I_p - I_{th}}
\]

Assume the drive current \( I = JA \), where \( J \) is the current density and \( A \) is the area of the active region.
PROBLEM E1 - PHYSICAL ELECTRONICS II

Solid State Electronics
An abrupt Si P-N Junction with a cross-section of $A = 10^{-4}$ cm$^2$ has the following properties:

<table>
<thead>
<tr>
<th>P side</th>
<th>N side</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_a = 10^{17}$ cm$^{-3}$</td>
<td>$N_d = 10^{15}$ cm$^{-3}$</td>
</tr>
<tr>
<td>$\tau_n = 0.1 \ \mu$s</td>
<td>$\tau_p = 10 \ \mu$s</td>
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<tr>
<td>$\mu_p = 200$ cm$^2$/V-s</td>
<td>$\mu_n = 1300$ cm$^2$/V-s</td>
</tr>
<tr>
<td>$\mu_n = 700$ cm$^2$/V-s</td>
<td>$\mu_p = 450$ cm$^2$/V-s</td>
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</table>

The junction is forward biased by 0.5 V.

a) What is the total forward current for an ideal p-n junction at + 0.5V bias?
   (Need to calculate $D_p$, $D_n$, $L_p$, $L_n$, $p_n$, $n_p$)

b) What is the total current at a reverse bias of – 0.5V?

c) Calculate the junction potential also called built-in potential $V_{bi}$

d) What is the total depletion capacitance ($C_j$) at -4 V reverse bias?

e) Calculate the depletion widths on the p-side of the junction $X_p$ and on the n-side $X_n$ for the following reverse biases -4 V and -10 V

Equations:

Ideal diode: $I = qA \left( \frac{D_p}{L_p} p_n + \frac{D_n}{L_n} n_p \right) \left( e^{qV/kT} - 1 \right) = I_0 \left( e^{qV/kT} - 1 \right)$

$D_p = \frac{kT}{q} \mu_p \quad L_p = \sqrt{D_p \tau_p}$

$D_n = \frac{kT}{q} \mu_n \quad L_n = \sqrt{D_n \tau_n}$
\[ X_p = \sqrt{\frac{2 \varepsilon_{si}}{q} (V_{bi} - V) \frac{N_d}{N_a(N_a + N_d)}} \]

\[ \varepsilon_{si} = \varepsilon * K_{si} \]

\[ X_n = \sqrt{\frac{2 \varepsilon_{si}}{q} (V_{bi} - V) \frac{N_a}{N_d(N_a + N_d)}} \]

Total depletion width

\[ W = X_p + X_n = \sqrt{\frac{2 \varepsilon_{si}}{q} (V_{bi} - V) \frac{(N_a+N_d)}{N_a-N_d}} \]

Depletion Capacitance:

\[ C_j = \sqrt{\varepsilon A \left[ \frac{q}{2(V_{bi} - V)} \frac{N_d N_a}{N_d + N_a} \right]}^{1/2} \]

**Physical Constants:**

Intrinsic carrier concentration in Si: \( n_i = 1.45 \times 10^{10} \, \text{cm}^{-3} \)

Permittivity in Vacuum \( \varepsilon = 8.8854 \times 10^{-14} \, \text{F/cm} \)

Dielectric constant of \( Si \): \( K_{si} = 11.7 \)

Elementary Charge: \( q = 1.602 \times 10^{-19} \, \text{C} \)

Boltzmann Constant: \( k = 1.38066 \times 10^{-23} \, \text{J/K} = 8.62 \times 10^{-5} \, eV/K \)

Thermal voltage at 300K: \( kT/q = 0.0259 \, \text{V} \)
Physical Electronics

1. Explain, using appropriate diagram, the main difference between GaAs and Germanium.
2. Based on your answer to question 1, explain and justify which material should be used for fabricating (1) transistor; (2) solar cell; (3) LED. Note that the answer might be none, both or one material.
PROBLEM E3 – PHYSICAL ELECTRONICS II

Plasma Science and Discharges

A cylindrical plasma tube with a diameter of 2 cm and length of 1 m is driven by a DC power source. The electric field in the plasma is $E = 20 \text{ volts/meter}$, the electron number density is $n_e = 10^{17} \text{ m}^{-3}$, the electron kinetic temperature is $T_e = 1 \text{ eV}$, and the current density across the tube is $J = 250 \text{ mA/cm}^2$.

a./ Calculate the mean thermal velocity of the electrons.

b./ Calculate the average drift velocity, $v_d$, of the electrons.

c./ Calculate the mobility of the electrons in the plasma. Assume a plasma resistivity of 0.8 $\Omega \text{.cm}$

d./ Calculate collision frequency for momentum transfer of the electrons.
PROBLEM F1 - Computer Systems

Microprocessors

Microprocessors
Write a subroutine that removes duplicate entries in a byte array for a Motorola 6811 microprocessor based system. The byte array has a base address of $2000 and the size (in bytes) of the initial array is stored in memory location $1000. At the termination of your subroutine, the array should have any duplicate entries removed and the updated size of the array stored in location $1000. You may assume that the initial array is unsorted and the array at termination can also be unsorted. Your code must be commented and you may include pseudocode or a flow chart to help explain the functionality of the code.

You may safely use memory locations $0001 to $00FF for storage of any temporary variables.

Details: Style - Write your code in a three column format, i.e.:
LABEL:* MNEMONIC OPERAND* (* use only when required / needed)

Example: LOOP: BRA LOOP

Symbols: The use of a # sign before an operand designates immediate addressing mode, $ - hexadecimal, % - binary.

Example: LDAA #$F0 – The value F0 hexadecimal is loaded into AccA.

Addressing modes: Immediate example: LDAA #$F0 (A ← $F0)
Direct example: LDAA $F0 (A ← M[$00F0])
Extended example: LDAA $00F0 (A ← M[$00F0])
Indexed example: LDAA 0, X (A ← M[X+0])

Available instructions:
- LDAA / STAA: Load / Store Accumulator A (one byte)
- LDAB / STAB: Load / Store Accumulator B (one byte)
- LDD / STD: Load / Store Accumulator D (A + B, double byte)
- LDY / STY: Load / Store index register Y (double byte)
- LDS / STS: Load/Store Stack Pointer (double byte)
- ABA: Add Accumulators A + B → A
- ABX / ABY: Add B to X/Y, IX/IY + 00:B → IX/IY
- ADCA / ADCB: Add with Carry to A/B, A/B + M + C → A/B
- ADDA / ADDB: Add Memory to A/B, A/B + M → A/B
- PSHA / PULX: Push / Pull Acc. Y on / from the stack
- INCA / DECA: Increment / Decrement AccA – Inherent addressing
- INCB / DECB: Increment / Decrement AccB
- INC / DEC: Increment / Decrement memory location contents
- INX / DEX: Increment / Decrement index register X
- INY / DEY: Increment / Decrement index register Y
- INS / DES: Increment / Decrement stack pointer

- BRA: Branch always - Relative addressing
- BEQ: Branch if equal to zero
- BNE: Branch if not equal to zero
- BGT: Branch if greater than zero
- BLT: Branch if less than zero
- BLE: Branch if greater than or equal to zero
- BMI: Branch if minus
- BPL: Branch is plus
- JMP: Jump to the given address – Absolute addressing
- RTS: Return from subroutine

- CLRA: Clear contents of AccA (A ← $00)
- CLRB: Clear contents of AccB (B ← $00)
- CLR: Clear memory location contents (M ← $00)
- CMPA: Compare AccA to memory (A – M)
- CMPB: Compare AccB to memory (B – M)
- CBA: Compare AccB to AccA (A–B)
- CPX: Compare index register X to memory (X – MM)
- CPY: Compare index register Y to memory (Y – MM)
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8-BIT ACCUMULATORS A & B
OR 16-BIT DOUBLE ACCUMULATOR D

INDEX REGISTER X
INDEX REGISTER Y
STACK POINTER
PROGRAM COUNTER

CONDITION CODES

- CARRY/BORROW FROM MSB
- OVERFLOW
- ZERO
- NEGATIVE
- I-INTERRUPT MASK
- HALF CARRY (FROM BIT 3)
- X-INTERRUPT MASK
- STOP DISABLE
Problem Description:

1. (5 points) Devise an SM Chart for a sequencer capable of detecting a sequence that begins with "01" is followed by one or more '0's, further followed by one or more '1's, ending with "01". Your sequencer does not have to account for overlaps. A couple of examples of sequences that should be detected are shown:
   "010101"
   "01000000101"
   "010111111101"
   "01000000111101"

2. (5 points) Sketch out the VHDL model for the sequencer for Part 1.
1. (7 points) Suppose the following code segment is going to be executed in the 5-stage pipeline of the SRC processor.

```
add r1, r2, r10
sub r10, r2, r1
sub r7, r10, r1
st r7, addr2
```

(a) (3 points) Find out all RAW hazards in the code segment.
(b) (2 points) How many cycles are needed to complete the execution if data forwarding is used? Explain how all the RAW hazards are resolved.
(c) (2 points) How many cycles are needed to complete the execution if data forwarding is not used? If an instruction needs to be stalled, list the number of cycles that this instruction has to be stalled.

2. (3 points) Please describe what is the difference between the RISC and the CISC architectures? What are advantages and disadvantages of each architecture?
PROBLEM F4 – COMPUTER SYSTEMS

Algorithms

Part 1 (6 points) You are given a connected undirected acyclic graph. Assuming the weight of each link is 1, find the most efficient algorithm to determine the diameter of the graph, where the diameter is the longest path possible between any two nodes in the graph.

Part 2 (4 points) Assuming the weight between two nodes is $W_{ij}$, find the diameter of the tree in terms of the weights between links.

In solving these problem, be sure to clearly state any assumptions you have had to make.
PROBLEM F5 – COMPUTER SYSTEMS

Data Structures

Recall the array-based implementation of class template Stack has the following data members:

```cpp
template <class T>
class Stack{
    // public function declarations here ...
    private:
    static const int MAX_STACK = 10;
    T items[MAX_STACK];
    int top; /* array index of top element of the stack;
            is -1 when stack is empty */
};
```

(a)

Write a member function

```cpp
template <class T>
bool Stack<T>::operator== (const Stack<T>& rhsStack) const
```

which checks to see if two stacks are equal (in other words, they have the same number of items, and all these items, from the top to the bottom, are equal).

(b)

A stack of integers aStack has the following private data:

```
top: 4
items: 8 0 0 4 7 10 -34323 0 67823 -78999
```

What is the output of the following code?

```cpp
int x;
while (!aStack.isEmpty()){
    aStack.pop(x);
    cout << x << " ";
}
```

Hint: Recall that top is the array index of the top of the stack.
Data Structures

Please provide pseudo code or diagram (explanations) for following questions

Given the input A (-1, 11, 9, 4, 0, 0, 3, 6),

2.1 Construct a binary search tree according to the input A sequence.

2.2 Add a node, 3, into this binary search tree?

2.3 Delete a node, 11, from this binary search tree?

2.4 Given another binary search tree with the input B sequence (4, 5, 7), how to join two trees (Input A and B) into one tree?