Department of Aerospace and Ocean Engineering
Graduate Study Specialization in Ocean Engineering

Written Preliminary Examination Information

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Test Format

Open book and notes. Answer six of the ten questions. There are two questions provided in each of five subject areas. It is required to select one question from each of the five subject areas. Select the sixth from the remaining five questions.

Subject Areas and Syllabi:

1. Applied Mathematics and Numerical Analysis (AM)

Applied Math: (Math 4564 & 4574)

References: Kreyszig, E., Advanced Engineering Mathematics, John Wiley and Sons, Inc., New York.

First-Order Differential Equations
Second-Order Linear Differential Equations
Higher-Order Linear Differential Equations
System of Differential Equations (Phase Plane and Stability)
Series Solution of Differential Equations, Special Functions
Laplace Transforms
Linear Algebra: Matrices, Vectors, Determinants
Vector Differential Calculus, Grad, Div, Curl
Vector Integral Calculus, Integral Theorems
Fourier series, Integrals, and Transforms

Numerical Analysis: (AOE 4404)

Reference: Burden, R. L., and Faires, J. D., Numerical Analysis, Seventh edition, Brooks/Cole.

Solutions of Equations in One Variable (except 2.6)
Interpolation and Polynomial Approximation (except 3.5)
Numerical Differentiation and Integration
Initial Value Problems for Ordinary Differential Equations
Direct Methods for Solving Linear Systems
Iterative Techniques in Matrix Algebra
Approximating Eigenvalues
Numerical Solutions of Nonlinear Systems of Equations

2. Fluids (F)

Aero/Hydrodynamics (5104)

Reference: K. Karamcheti, Principles of Ideal-Fluid Aerodynamics, 2nd Edition, Kreiger, 1980: All Chapters except 7

Stress in a Fluid
Description of Fluid Motion
Equations of Motion
Bernoulli's Equation
Steady and Unsteady Irrotational Flow
Circulation and Lift for an Infinite Wing
Use of the Complex Potential
Airfoils, Thin Airfoil Theory, Finite Wing Theory
Flow with Vorticity
Flow Past a Slender Body

3. Structures (S)

Ship Structures (AOE 3224)

Reference: O.F. Hughes, *Ship Structural Design*, SNAME, 1998: Chapters 1, 3, 5, 7 and 9

Introduction to Rationally-Based Structural Analysis of Ocean Structures
Hull Girder Loading and Structural Response of Ships
Frame Analysis
Basic Aspects of Finite Element Analysis
Elastic Plate Bending
Plastic Hinge Theory
Design of Plates With Allowable Permanent Set
Plate Vibration

Computer Based Design Of Ship Structures (AOE 4274)

Reference: O.F. Hughes, *Ship Structural Design*, SNAME, 1988: Chapters 11 through 14

Reliability-Based Structural Design of Ships
Principles of Coarse Mesh Finite Element Modeling of Ships
Use of an Interactive Graphical Finite Element Modeler
Buckling of Columns and Beam Columns
Buckling and Ultimate Strength of Plates
Buckling and Ultimate Strength of Stiffened Panels
Ultimate Strength of a Ship Hull

4. Naval Architecture (NA)

Naval Architecture and Ship Resistance (AOE 3204, 3264, 5304)

References: R., B. Zubaly, "Applied Naval Architecture", SNAME, 1996: Chapters 2-6; and E.V. Lewis, "Principles of Naval Architecture (PNA)", SNAME, 1988: Chapters 1-3, 5, 6.

Ship geometry and lines drawing
Area, volume, moment and center calculations
Ship characteristics
Curves of form
Intact transverse stability, heel
Trim and longitudinal stability
Stability at large angles
Damage stability
Safety criteria and assessment
Resistance and powering

5. Ship Dynamics (SD)

Advanced Ship Dynamics (AOE 5334)

References: Lloyd, ARJM, Seakeeping, "Ship Behavior in Rough Weather", 1998: Chapters 1-11, 14; and E.V. Lewis, "Principles of Naval Architecture (PNA)", SNAME, 1988: Chapter 8.

Transient and steady-state response
Ship equations of motion
Forces and motion/force coefficients
Model testing
Strip theory
Lewis forms
5 DOF coupled solution
Regular waves
Random seas and ocean spectra
Events and criteria

Questions:

1. Applied Mathematics and Numerical Analysis (AM)

Problem #1 (AM1)

(i) Explain what are eigenvalues and eigenvectors of a matrix. Give at least two applications where eigenvalues and eigenvectors are used in Structural Mechanics.

(ii) Using the Power method, determine the largest eigenvalue of the following matrix. Using an appropriate starting vector, perform three iterations.

$$\begin{bmatrix} 2 & -1 \\ -1 & 1 \end{bmatrix}$$

(iii) Using the method of diagonalization, find the general solution of:

$$\frac{d}{dt}\left\{ \begin{matrix} y_1 \\ y_2 \end{matrix} \right\} = \begin{bmatrix} -3 & 1 \\ 1 & -3 \end{bmatrix} \left\{ \begin{matrix} y_1 \\ y_2 \end{matrix} \right\} + \left\{ \begin{matrix} -6 \\ 2 \end{matrix} \right\} e^{-2t}$$

Problem #2 (AM2)

(i) Verify that the following is a central difference approximation to the fourth-order derivative and determine the order of the truncation error.

$$f''''(0) = \frac{f(-2h) - 4f(-h) + 6f(0) - 4f(h) + f(2h)}{h^4}$$

(ii) Numerical differentiation is an unstable process. Explain.

(iii) Using 3-point Gauss integration scheme, obtain

$$I = \int_{1.2}^{2.8} e^{x^2}\, dx$$

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2. Fluids (F)

Problem #3 (F1)

Assuming irrotational, incompressible flow, solve for the velocity potential in the region $0 \le z < \infty$, $0 \le x < l$ subject to the boundary conditions of no flow through the $x = 0$ and $x = l$ planes and, at $z = 0$, $\frac{\partial^2 \phi}{\partial t^2} = \frac{\partial \phi}{\partial z}$. Assume that there is no flow in the y direction, i.e., it is a two spatial dimension problem. Also assume that the flow is time harmonic, i.e., $f \propto e^{iwt}$.

Problem #4 (F2)

For fluid problems on a geophysical scale, it is often necessary to take into account the earth's rotation by adding the Coriolis acceleration, $2\vec{\Omega}\times\vec{V}$, to the fluid acceleration expressed in earth fixed coordinates. Here, $\vec{V}$ is the velocity vector in earth fixed coordinates and $\vec{\Omega}$ is the earth's rate of rotation vector which can be considered a constant vector. If we consider steady flow in an inviscid, incompressible fluid where Coriolis acceleration is important, under what conditions may the Bernoulli equation be applied? Specifically address the cases of zero and nonzero vorticity.

3. Structures (S)

Problem #5 (S1)

When a mobile crane on an aircraft carrier lifts a damaged aircraft, each tire carries a force of 64000 N. The tire has a square footprint and a pressure of 1.6 MPa. A typical panel of deck plating is 500 mm wide and 2000 mm long. The material properties are E = 208 GPa, σ_Y = 240 MPa and ν = 0.3. Determine the plate thickness if the maximum permanent set is not to exceed 7 mm.

Since this is a wheel load the correct method is Multiple Location. But for examination purposes you are to calculate the plate thickness separately, using both methods. [Doing it for the same plate means that some quantities that you calculate in (a) can be reused in (b)]. In both cases use the nearest relevant figure in the textbook.

(a) Calculate the thickness using Single Location.

(b) Calculate the thickness using Multiple Location.

Problem #6 (S2)

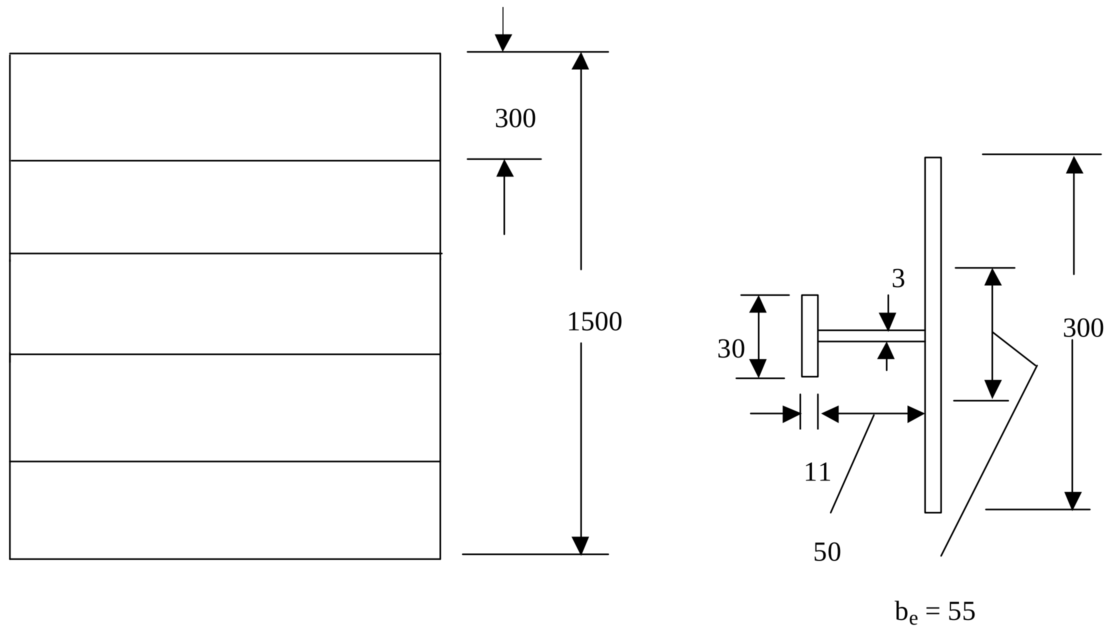
The attached figure shows a stiffened panel in an aluminum high speed patrol boat. The material is Al 2024-T3 for which the material properties are σ_Y = 280 MPa, E = 69000 MPa and ν = 0.3. The plating is 6 mm thick. Due to pressure on the panel each stiffener carries a uniform distributed load q = 9.13 N/mm, which causes a maximum "dead load" bending moment $M_0 = qL^2 / 8 = 1.141\times10^6$ Nmm and a maximum "dead load" deflection $\delta_0 = 5qL^4 / (384\, EI)$ = 2.89 mm. The stiffener has an eccentricity Δ = 2.14 mm.

a) Calculate the axial compressive stress that would cause collapse of the stiffener as a *simply supported* beam-column. Assume that the plating has already buckled and that the effective width of plating that acts as a plate flange of the stiffener is 55 mm. The properties of a section with a plate flange of width b_e = 55 mm are:
A = 810 mm^2 $\quad$ $I = 0.596 \times 10^6$ mm^4 $\quad$ $\rho^2 = I/A$ = 736 mm^2
and c = distance from neutral axis to plate midthickness = 29.25 mm.

b) Calculate the elastic buckling stress for a typical 300 × 1000 × 6 mm plate (between stiffeners) simply supported on all edges, for two separate compressive loads:

   a. An applied stress acting in the plate's long direction.

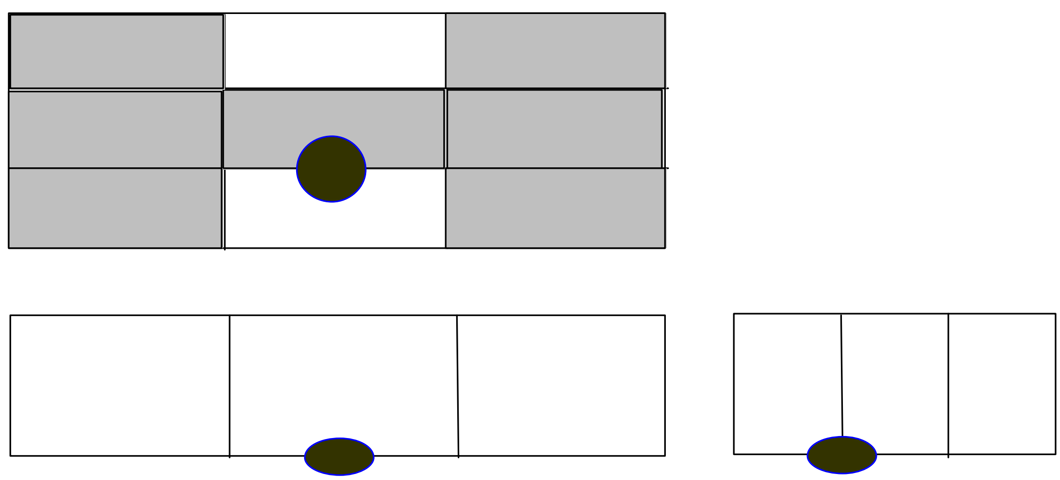
   b. An applied stress acting in the plate's short direction.



4. Naval Architecture (NA)

Problem #7 (NA1)

A partially-filled oil barge strikes bottom, puncturing a single cargo oil tank and a single empty ballast tank as shown, and then the barge floats free. Assume that the center of the hole is on the tank boundary. Shaded areas are cargo oil tanks, all of which are less than 80 percent full before grounding. Unshaded areas are ballast tanks, all of which are empty before grounding. All tanks have equal dimensions.



- Barge Length = 600 ft; Beam = 135 ft; D = Depth = 50 ft
- Before grounding, the mean draft of the barge was 25 feet with zero trim and heel. KG = 30 feet
- The damaged cargo tank was 50% full with cargo oil before grounding and vented to the atmosphere. The damaged ballast tank was empty. All tanks have the same dimensions and a permeability of 95%.
- Cargo oil specific gravity = SG_{oil} = 0.8

a. Immediately after this barge has grounded and floated free, will there be an oil spill?

b. What is the final level of oil and/or water in the cargo tank?

c. What is the final heel angle of the barge.

Problem #8 (NA2)

5. Ship Dynamics (SD)

Problem #9 (SD1)

The heave response spectrum, SR(ω), shown as a dashed line in Figure 1 is for an oil tanker with a heave frequency response function, H(ω), shown as a solid line in Figure 1.

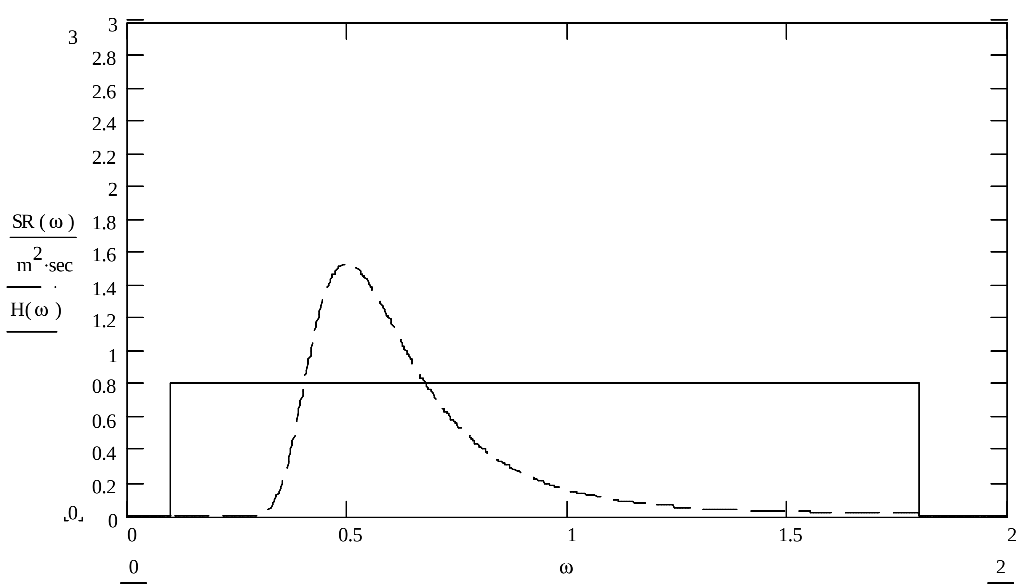


Figure 1

1a. Sketch (on Figure 1) the wave energy spectrum, $S(\omega)$, exciting this response [$m^2 sec$]?

1b. What is the approximate modal frequency for the wave energy spectrum [Hz]?

1c. Assuming that this modal frequency represents the most probable Ochi modal frequency for this sea, what is the corresponding significant wave height [m]? What is m_0 for this wave spectrum [m^2]?

1d. If the second moment of the response spectrum is: $m_{2R} = .261 \frac{m^2}{sec^2}$. What is the second moment of the wave spectrum [$m^2 sec^2$]?

1e. What is the characteristic wave height over a period of 3 hours with a 0.01 probability of exceedance [m]?

Problem #10 (SD2)

After preliminary design, a new passenger ship has characteristics listed in the following table. A roll-only model test is conducted for this preliminary design. The model length is 5 meters and the test is in regular waves with frequency 0.5 rad/sec at a ship speed of 10 knots in beam seas. The model test is done in fresh water. The model test forced roll amplitude is 11.5 degrees and the applied model roll moment is 35 N*m with an applied roll moment phase angle of 20 degrees. Calculate the ship roll coefficients using the model test results.

a. Complete the following table:

Characteristic	**Ship**	**Model**
LBP	70 m	
B	15 m	
T	6 m	
C_B	0.55	
Displaced volume	3465 m^3	
Displaced mass	3552 tonne	
Displacement	3.483×10^7 N	
c_{44}	6.838×10^7 N m	
μ		
ω	0.5 rad/sec	
U	10 knots	

ω_e		
A_{44}		
b_{44}		

The same model is run into regular head seas with a model test wave amplitude of 0.2 meters and frequency 0.5 rad/sec. The model length is 5 meters. The full scale ship length is 70 meters and full scale ship speed is 10 knots. The model pitch amplitude is 2 degrees and the pitch phase angle is 165 degrees. The model heave amplitude is 0.1 meters and the heave phase angle is 70 degrees. Assume the center of flotation is at midship and neglect swell-up and bow wave effects.

b. What is the wave number, k, for the model test? [1/m]

c. What are the complex amplitudes (x3bar and x5bar) for heave and pitch of the model. [mrad]

d. What is the complex amplitude of the vertical motion (s3bar) for a point at the forward perpendicular (baseline, centerline) of the ship? [m]

e. What is the amplitude and phase angle of the relative motion between this point and the regular wave surface? [m]

f. Neglecting swell-up and the ships bow wave, would you expect the model deck at the bow to submerge? The model has a freeboard at the bow of 0.2 meters.

Ship Dynamics

1) Given a tanker moored as shown in Figure 1, you are to estimate the forces acting on the mooring system for the proposed shallow water facility. The force that two round caissons must withstand will be calculated based upon the assumption that the tanker does not move. You are to calculate the oscillatory force on a super tanker (length 1000 ft, beam 150 ft, draft 48 ft) in water of depth 50 ft. The incident waves are long waves of amplitude 1 ft from the beam. (Note: the velocity potential for finite-depth waves propagating in the positive x-direction is given by $\phi(x,z,t) = Re\left[\frac{ig\zeta_o}{\omega}\frac{\cosh k(z+h)}{\cosh kh}e^{i(\omega t - kx)}\right]$).

a) Argue that a reasonable approximation to the incident and diffracted wave potential near the tanker would be standing waves. Write the velocity potential for the transmitted wave as a sum of the incident and diffracted wave potential.

b) Show that a standing wave solution, *ie* your velocity potential in part a, satisfies Laplace's equation, the linearized combined free surface boundary condition, the body boundary condition on the side where the waves are incident, and the bottom boundary condition. Show that it does not generally satisfy the body boundary condition on the lee side or in the gap under the hull.

c) Comment on the far field radiation conditions as modelled by standing waves.

d) By integrating the linearized dynamic pressure, $P = -\rho\frac{\partial\Phi_T}{\partial t}$, show that the wave exerts a force of $F(t) = 2\rho g\zeta_o\frac{\tanh kh}{k}\cos(\omega t)$ per unit length of tanker side at x=0.

e) Given the dimensions above, what is the force acting on each caisson?

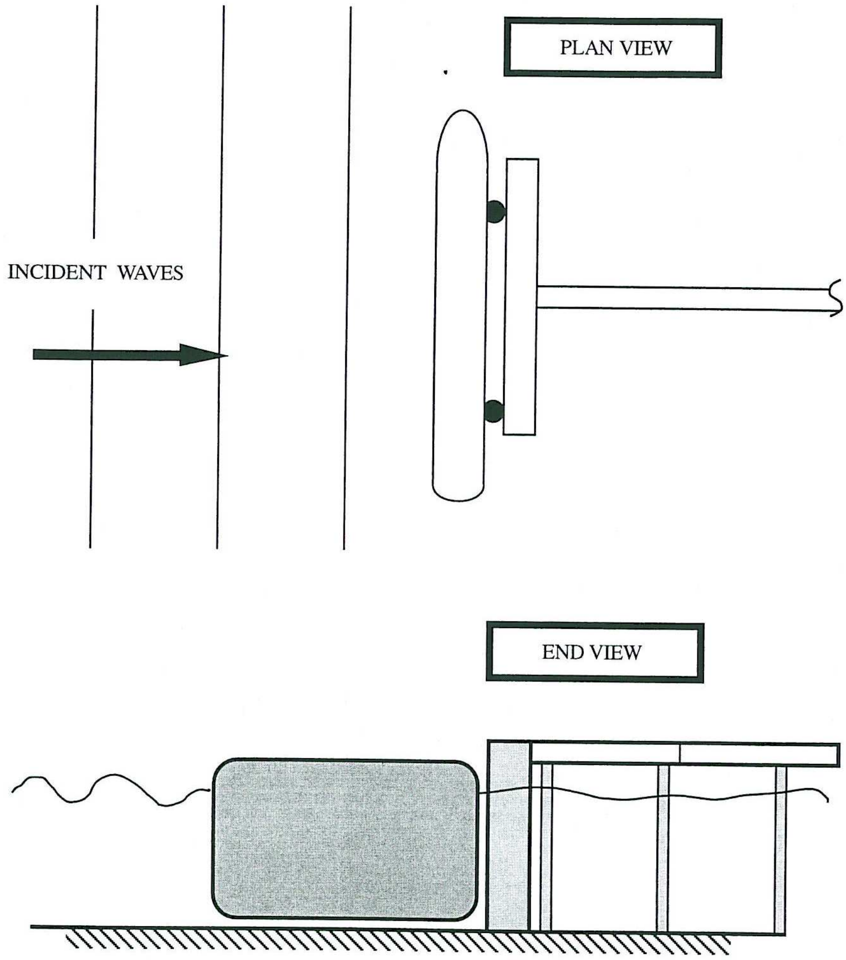


Figure 1: Figure for Problem 1

Ship Dynamics

2) You are given the idealized wave spectrum $S+(\omega)$ shown in Figure 2. An oil exploration ship has a response amplitude operator for heave shown in Figure 3. Based upon this information, answer the following questions.

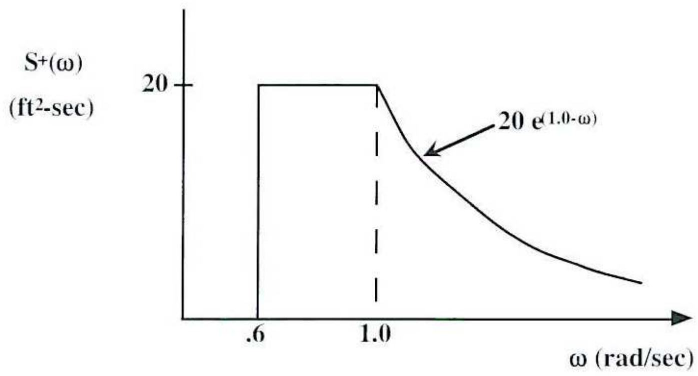


Figure 2: Idealized wave spectrum for Problem 2

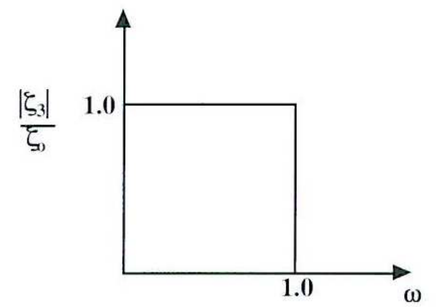


Figure 3: Heave RAO for Problem 2

a) What is the value of the root mean square heave displacement?

b) What is the value of the root mean square heave acceleration?

c) Assuming the ship stays in the sea state a long time, on average, how often will the amplitude of the heave acceleration envelope curve exceed 0.5 g (where g is the gravitational constant)? Give your answer in convenient time units.

Mathematics
Using Laplace Transforms, find a general solution to the initial value problem:

$\frac{d^3y(t)}{dt^3} + 4\frac{d^2y(t)}{dt^2} + 5\frac{dy(t)}{dt} + 2y(t) = 10$

$y(0) = 0$

$\frac{dy(0)}{dt} = 0$

$\frac{d^2y(0)}{dt^2} = 3$