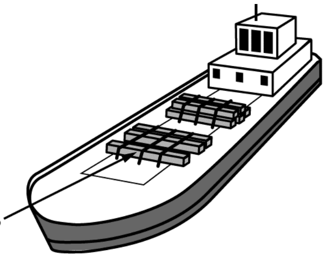

4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number *N* of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \text{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

STOP

END OF EXAM

Question 4

10 points total **Distribution of points**

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) LO 1.E.1.2, SP 6.4; LO 3.B.2.1, SP 1.1, 1.4, 2.2; LO 5.B.10.1, SP 2.2
4 points

Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

For equating the correct forces acting on the boat-steel system: gravity (weight) and the buoyant force		1 point
For correctly calculating the weight of the boat-steel system		1 point
$W_{system} = (M_b + N_{steel}\rho_{steel}V_{steel})g$, where N is the number of steel beams (must clearly use mass of boat)		
For correctly calculating the buoyant force		1 point
$F_b = \rho_{water} g V_b$		
For algebraic manipulation of the equations to get an expression for the number of beams consistent with the equations for weight and buoyant force		1 point
$(M_b + N\rho_{steel}V_{steel})g = \rho_{water} g V_b$		
$N = (\rho_{water}V_b - M_b)/\rho_{steel}V_{steel}$		

(b) LO 6.C.1.1, SP 6.4, 7.2; LO 6.E.1.1, SP 6.4, 7.2; LO 6.E.3.3, SP 6.4, 7.2
4 points

The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

The constructive interference is between light reflected from the air-oil interface and light reflected from the oil-water interface.		
For indicating that the green appearance is the result of interference of light from two waves		1 point
For indicating that there is a phase shift due to one of the reflections		1 point
For indicating that the wavelength of the light is different in air and oil		1 point
For indicating that there is a path-length difference of the light reflected from the two surfaces		1 point

Question 4 (continued)

Distribution of points

(c) LO 5.F.1.1, SP 2.2, 7.2
2 points

Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \text{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

For an attempting to apply the principle of continuity		1 point
$A_{wide}v_{wide} = A_{narrow}v_{narrow}$		
$(60\ \text{m})(\text{depth})(5\ \text{km/hr}) = (30\ \text{m})(\text{depth})(v_{narrow})$		
For correctly calculating the speed		1 point
$v_{narrow} = 10\ \text{km/hr}$		

Learning Objectives (LO)

LO 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. [See Science Practices 4.1, 6.4]
LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, 2.2]
LO 5.B.10.1: The student is able to use Bernoulli's equation to make calculations related to a moving fluid. [See Science Practice 2.2]
LO 5.F.1.1: The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). [See Science Practices 2.1, 2.2, 7.2]
LO 6.C.1.1: The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. [See Science Practices 6.4, 7.2]
LO 6.E.1.1: The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. [See Science Practices 6.4, 7.2]
LO 6.E.3.3: The student is able to make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. [See Science Practices 6.4, 7.2]