IB Physics
FA 10.1 - Fluid Statics

Name_____

Show your work, round to the correct significant figures, circle your answers, and label them with units.

(1 atm = 1.013×10^5 Pa = 101.3 kPa = 14.7 psi = 760 Torr; 1 m^3 = 1000 liters; $p_{absolute} = p_{gauge} + 1$ atm;)

When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1. A circular porthole in an airplane has a diameter of 37.0 cm. If there is a pressure difference of 31,510 Pa from one side of the window to the other, what is the net force pushing out on the porthole?

2. A cannon ball has a density of 7820 kgm^{-3} and a mass of 23.2 kg. What is its radius if it is perfectly spherical?

3. A hydraulic jack has an input piston diameter of 0.850 cm, and an output piston diameter of 4.50 cm. What force must you exert on the input piston to lift a 1210 kg car?

4a. An empty beaker 8.20 cm in diameter is pushed 10.3 cm into mercury ($\rho = 13.6 \times 10^3$ kg m^{-3}). What is the net upward force on the bottom of the beaker? (Assume the pressure above the mercury is 1 atm)

4b. What is the gauge pressure in PSI at a depth of 8.50 m in fresh water? ($\rho = 1000.$ kg m^{-3})

4c. At what depth in ocean water ($\rho = 1025$ kgm^{-3}) is the absolute pressure 8320 Torr?

5a. A cylinder has a radius of 0.920 cm and is 25.0 cm long. How far will it sink into a mixture with a density of 865 kg m^{-3} if it has a mass of 37.5 grams assuming it is weighted so it floats vertically?

5b. What upward force would you need to exert on a 11.5 kg piece of Murralite (ρ = 1666 kgm^{-3}) submerged in the dead sea where the water has a density of 1240 kgm^{-3} to keep it from sinking?

5c. A hot air balloon is 9.00 m in radius (assume it is spherical) and contains hot air with a mean density of 0.950 kgm^{-3}. Calculate the lifting capacity (in N) of the hot air if it is surrounded by air with a density of 1.31 kgm^{-3}

Worksheet 10.1: Fluid Mechanics - Statics

Pressure: P = F/A (memorize area of circle, and rectangle)

1. A force of 23,450 N is exerted on a rectangular window that measures 2.30 m by 0.980 m. What is the pressure? (1.04E4 Pa)
2. What is the force of 2100. psi over a circular flange with a radius of 8.5 inches? (476658 lbs ≈ 4.8E5 lbs)
3. What is the total area in m^2 of some snowshoes, if a 75 kg person does not exert a pressure greater than 1.2×10^3 Pa? ($0.61\ m^2$)

Pressure conversions

Converting units of pressure.

1.00 atm = 1.013×10^5 Pa = 101.3 kPa = 760. Torr = 14.7 psi

4. Convert 450. Torr to Pa. (6.00E4 Pa)
5. Convert 3.20 ATM to Pa. (3.24E5 Pa)
6. Convert 835 Torr to psi (16.2 psi)
7. Convert 35 psi to Pa. (2.4E5 Pa)
8. Convert 16.7 kPa to Pa. (1.67E4 Pa)
9. Convert 2350 Pa to psi (0.341 psi)

Gauge and absolute pressure: $P = P_G + 1$ atm

10. What is 0.45 atm gauge in absolute? (1.45 atm)
11. What is 34.0 psi gauge in absolute? (48.7 psi)
12. What is 4.50 psi absolute in gauge? (-10.2 psi)
13. What is 3.415×10^5 Pa in absolute in gauge? (2.402E5 Pa)
14. What is 3.60 atm absolute in gauge? (2.60 atm)
15. What is 45.0 psi absolute in gauge (30.3 psi)
16. What is 34,500 Pa gauge in absolute? (1.358E5 Pa)

Gauge and unit conversions (on the assessments)

17. What is 12.0 psi gauge in Pa absolute? (1.84E5 Pa)
18. What is 78.0 kPa absolute in Torr gauge? (-175 Torr)
19. What is 34.5 psi gauge in atm absolute? (3.35 atm)
20. What is 0.835 atm absolute in Torr gauge? (-125 Torr)
21. What is 8.45 psi gauge in kPa absolute? (160. kPa)
22. What is 34,500 Pa absolute in atm gauge? (-0.659 atm)
23. What is 1.30 atm gauge in kPa absolute? (233 kPa)
24. What is 7810 Pa absolute in kPa gauge? (-93.5 kPa)
25. What is -34.9 kPa gauge in psi absolute? (9.64 psi)
26. What is 512,000 Pa absolute in Torr gauge? (3081 Torr)

Density ρ = m/V (memorize volume of rectangular solids, cylinder)

27. What is the density (in kg m^{-3}) of a cube that is 11.0 cm on a side, and has a mass of 894 grams? ($672\ kgm^{-3}$)
28. What is the mass of a gold brick that measures 26.0 cm x 8.00 cm x 12.0 cm? ($\rho = 19.3 \times 10^3\ kgm^{-3}$) (48.2 kg)
29. A sphere that contained 45.0 kg of air would have what radius? ($\rho = 1.29\ kgm^{-3}$) (2.03 m)
30. What is the density of a shot put that has a diameter of 12.0 cm and a mass of 7.26 kg? ($8020\ kgm^{-3}$)
31. What is the mass of mercury ($\rho = 13.6 \times 10^3\ kgm^{-3}$) in a (cylindrical) cup that is 9.00 cm tall, and 11.0 cm in diameter? (11.6 kg)

Pascal's Principle: F/A = F/A

32. An engineer designs a hydraulic jack to lift 4560 kg. If the output cylinder is 8.20 cm in diameter, and the input cylinder is 0.420 cm in diameter, what input force is required? (117 N)
33. A hydraulic jack lifts 620. kg of mass with an input force of 24.0 N. What is the diameter of the input cylinder if the output cylinder has a diameter of 12.6 cm? (0.791 cm)
34. If you exert 4.45 N on the 0.920 cm diameter input cylinder of a hydraulic jack, what force does the 6.80 cm diameter output cylinder exert? (243 N)
35. A brake cylinder exerts 342 N of force with an input force of 55.2 N. What is the diameter of the brake cylinder if the master cylinder has a diameter of 1.21 cm? (3.01 cm)
36. A brake cylinder exerts 416 N of force on the rotor. What is the input force if the master cylinder has a diameter of 2.30 cm, and the brake cylinder is 4.50 cm in diameter? (109 N)

Hydrostatic Pressure: $P = P_o + \rho gd$

Simple:

37. What is the pressure at a depth of 125 m in the ocean? (ρ = 1025 kgm^{-3}) Assume there is 1 atm above the water. ($1.36x10^6$ Pa)
38. What is the gauge pressure at a depth of 1.67 m in mercury? ($\rho = 13.6x10^3$ kgm^{-3}) Assume there is 1 atm above the surface. ($2.23x10^5$ Pa)
39. At what depth in fresh water (ρ = 1000. kgm^{-3}) is the absolute pressure $2.31x10^6$ Pa. Assume there is 1 atm above the water. (225 m)

More Complex: (These are like the assessment questions. Use Pa, and P = F/A)

40. At what depth below the ocean (ρ = 1025 kgm^{-3}) is the absolute pressure 100. psi? (Assume the pressure above the surface is 1 atm) (58.5 m)
41. A submarine is 45.2 m below the surface of a lake (ρ = 1000. kgm^{-3}). What is the net force exerted on a 85.0 cm diameter hatch. Assume there is 1 atm above the water, and in the submarine? ($2.52x10^5$ N)
42. There is a gauge pressure of 812 Torr at a depth of 14.2 m in a fluid. What is the density of the fluid? Assume there is 1 atm above the fluid. (777 kgm^{-3})
43. At what depth in the dead sea (ρ = 1240 kgm^{-3}) does the water exert a force of 23,500 N on a 9.20 cm diameter porthole? Assume there is 1 atm above the water. (282 m)
44. A tank contains Liquid nitrogen (ρ = 808 kgm^{-3}). At a depth of 13.5 m there is an absolute pressure of 313.7 kPa. What is the pressure at the top of the liquid in psi? (30.0 psi)

Buoyancy ($B = \rho_f V_f g$)

Simple: (I walk you through all the steps with separate questions)

45. What is the buoyant force on a block of wood that is 2.95 cm x 4.50 cm x 4.50 cm submerged in fresh water? (ρ = 1000. kgm^{-3}) If the wood has a density of 362 kgm^{-3}, what is its mass? What is its weight? What downward force would you need to exert to hold it under the water? (0.586 N, 0.0216 kg, 0.212 N, 0.374 N)
46. A 0.120 kg aluminium (ρ = 2680 kgm^{-3}) mass is submerged in alcohol with a density of 789 kgm^{-3}. What is the volume of the aluminium mass? What is the buoyant force acting on the mass? What is the weight of the mass? If the mass is resting on the bottom of the beaker, what is the normal force the beaker exerts on the mass? What is the apparent "mass" of the aluminium? (The mass that would weigh what the normal force is...) (4.48E-5 m^3, 0.347 N, 1.18 N, 0.831 N, 0.0847 kg)
47. A rectangular block of wood has a density of 345 kgm^{-3} and measures 85.2 cm x 64.2 cm x 20.0 cm. It floats in water (ρ = 1000. kgm^{-3}) with a large face down in the water. What is its mass? What volume of water must it displace to float? (What is the volume of water that has this mass?) How far up the 20.0 cm side does the water come so that the block displaces this volume of water? (85.2 cm x 64.2 cm x X = volume) How much of the 20.0 cm dimension sticks up above the water? (37.7 kg, 0.0377 m^3, 0.069 m or 6.90 cm, or 13.1 above)

More Complex - I just ask you the last part.

48. What downward force would you need to exert to keep a 14.0 cm radius sphere with a density of 253 kgm^{-3} submerged in a fluid with a density of 965 kgm^{-3}? (80.3 N)
49. What upward force would you need to exert on a 52.1 kg piece of basalt (2920 kgm^{-3}) submerged in the dead sea where the water has a density of 1240 kgm^{-3} to keep it from sinking? (294 N)
50. A 13.25 gram hydrometer is a 1.12 cm diameter tube weighted on one end so it floats upright in a liquid. If it is 25.0 cm long, but floats with 7.80 cm exposed to air, what is the density of the liquid? (782 kgm^{-3})
51. A hot air balloon is 8.74 m in radius (assume it is spherical) and contains hot air with a mean density of 0.9486 kgm^{-3}. Calculate the lifting capacity of the hot air if it is surrounded by air with a density of 1.34 kgm^{-3}. (10,740 N)
52. A glass (2580 kgm^{-3}) cylindrical stirring rod is 5.02 mm in diameter and 18.0 cm long. What force do I need to exert on it to hold it vertically at rest with the tip submerged in acetone (791 kgm^{-3}) to a depth of 11.0 cm? ($7.33x10^{-2}$ N)
53. A rectangular piece of wood that measures 13.0 cm x 15.2 cm x 3.78 cm floats face down in a fluid with a density of 893 kgm^{-3} with 2.93 cm of the 3.78 cm dimension submerged. What is the density of the wood? (692 kgm^{-3})
54. A 5.34 kg piece of rock can be supported by a force of 40.4 N when submerged in water with a density of 1008 kgm^{-3}. What is the density of the rock? (4406 kgm^{-3})
55. A 1.28 kg piece of Styrofoam float material can be held under water (ρ = 1000. kgm^{-3}) with a downward force of 328.7 N. What is the density of the Styrofoam? (36.8 kgm^{-3})

IB Physics
FA 10.2 - Fluid Dynamics

Name_____

Show your work, round to the correct significant figures, circle your answers, and label them with units.

When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1a. Water flows at 0.140 m/s down a pipe with an inner diameter of 1.27 cm. If the pipe widens to an inner diameter of 5.08 cm, what is its velocity?

1b. Water flows at 1.20 m/s down a 3.20 cm diameter hose. What time will it take to fill a cylindrical tank that is 6.10 m in diameter to a depth of 180. cm?

2a. How fast does air leak out of a small hole in a tire that is at 32.0 psi gauge? Ignore viscosity, and use 1.29 kgm^{-3} as the density of air.

2b. Water issues from hole in the side of a water tank at 18.0 m/s. What is the height of the water in the tank above the hole? (ρ = 1000. kgm^{-3}) Assume atmospheric pressure above the water in the tank and at the hole.

2c. The air (ρ = 1.29 kgm^{-3}) is traveling at 63.0 m/s over the top of a wing, and 61.0 m/s over the bottom of a wing. What is the pressure difference from one side to the other?

3. Water (ρ = 1000. kgm^{-3}) is moving at 2.35 m/s down a pipe with an inner diameter of 3.40 cm and is at a pressure of 9830 Pa at a height of 1.17 m. It changes elevation and the pipe narrows to 2.95 cm inner diameter and the pressure changes to 12,400 Pa. What is the new elevation? (Assume laminar flow. haha)

4a. A tiny drop of water ($\rho = 1000.\ kgm^{-3}$) has a terminal velocity of 0.00315 m/s through air with a viscosity of $1.81x10^{-5}$ Pa s. What is its radius? (Ignore the buoyant force of the air)

4b. A tiny grain of bapepper ($\rho = 2130\ kgm^{-3}$) is 1.20 microns in diameter. What speed does it settle in water?
($\rho = 1000.\ kgm^{-3}$, $\eta = 1.002x10^{-3}$ Pa s) (Don't ignore the buoyant force of water)

5. What is the maximum speed water can move down a 5.08 cm diameter pipe if it is to have a Re_r (what our equation calculates) that is less than 1000? (use $\rho = 1000.\ kgm^{-3}$, $\eta = 1.10x10^{-3}$ Pa s)

Worksheet 10.2: Fluid Mechanics - Dynamics

Volume flow rate. ($Av = {}^{\Delta V}/_{t}$) (memorize volumes of cylinders, spheres, and rectangular solids)

1. Water flows at 0.854 m/s down a 1.59 cm diameter hose. What time will it take to fill a circular kiddie pool that is 1.75 m in diameter to a depth of 37.0 cm? (5250 s)
2. An HVAC duct that is 1.02 m in diameter supplies air to a 10.0 m x 4.20 m x 21.0 m room at a rate of 3.50 ACH. What is the air speed in the duct? (3.50 ACH means it replaces the air 3.50 times per hour, so it does it once in (3600 s)/3.5 seconds) (1.05 m/s)
3. A pump delivers 180. liters per minute. What speed does the water travel through its 4.15 cm diameter outlet pipe? What time would it take for the pump to fill a rectangular tank that is 2.1 m x 3.3 m x 5.4 m? (2.22 m/s, 12,500 s)
4. A classroom is 32.0 feet by 58.5 feet and 8.10 feet high. If air flows 8.65 f/s down a 1.50 foot x 1.00 foot air duct, what time in minutes does it take to replace the air in the room? (19.5 minutes)
5. A pipe bursts in a classroom that is 12.0 m x 35.0 m in floor area. If it is a 5.08 cm diameter pipe, and the water is going 20.3 m/s, what depth will the water be in a hour if it does not leak? (35.3 cm)

Continuity (Av = Av)

6. A 0.75 inch pipe with water going 4.5 inches per second narrows to 0.50 inches inner diameter. What is the velocity in the narrow part? (10. inches/sec)
7. Air flows at 0.450 m/s down a duct that is 24.0 cm x 62.0 cm. If it widens to 35.0 x 62.0 cm, what is the air velocity there? (0.309 m/s)
8. A circular 2.50 cm diameter pipe has a flow velocity of 56.0 cm/s. What is the diameter of the pipe if the flow velocity slows to 13.0 cm/s? (5.19 cm)
9. A fire hose sprays water at 34.0 m/s out of a nozzle that is 2.50 cm in diameter. What is the diameter of the supply line if the velocity is 3.68 m/s (7.60 cm)
10. A river with a strangely rectangular channel is 20.0 m wide. At a spot where it is 6.30 m deep, the water moves at a stately 0.0850 m/s. Later there is a rapids where the water moves at 3.20 m/s. How deep is it there on the average? (Assume the channel is more or less rectangular in cross section) (0.167 m)

Bernoulli - 2 or 3 terms: ($P + \rho gh + \frac{1}{2}\rho v^2 = P + \rho gh + \frac{1}{2}\rho v^2$)

1.00 atm = 1.013×10^5 Pa = 101.3 kPa = 760. Torr = 14.7 psi, $\rho_{water} = 1000.\ kgm^{-3}$, $\rho_{air} = 1.29\ kgm^{-3}$

11. Water issues from hole in the side of a water tank at 12.0 m/s. What is the height of the water in the tank above the hole? ($\rho = 1000.\ kgm^{-3}$) Assume atmospheric pressure above the water in the tank and at the hole. (7.34 m)
12. Air ($\rho = 1.29\ kgm^{-3}$) streams at 6.70 m/s through a hole in a wall. What is the pressure difference from one side to the other? (29.0 Pa)
13. The air is traveling at 45.0 m/s over the top of a wing, and 43.0 m/s over the bottom of a wing. What is the pressure difference from one side to the other? (114 Pa)
14. Water is at 1.035×10^5 Pa in a level pipe where the velocity is 2.40 m/s. If the pressure drops to 1.024×10^5 Pa, what is the velocity? (2.82 m/s)
15. Water moves at 1.70 m/s down a level pipe at a pressure of 1.015×10^5 Pa. What is the pressure if the water speeds up to 4.92 m/s? (9.08×10^4 Pa)

Bernoulli - complex

16. Water flows at 4.50 m/s down a 2.10 cm diameter pipe at a pressure of 9.92×10^4 Pa in the crawlspace. When the pipe is 1.20 m higher than this the pressure is 9.52×10^4 Pa. What is the velocity of the water in the pipe? What is the pipe diameter? (2.17 m/s, 3.02 cm)
17. Water moves at 3.50 m/s down a 4.80 cm diameter pipe at an elevation of 3.80 m and a pressure of 1.26×10^5 Pa. At a different elevation the pipe narrows to 3.60 cm in diameter and is at a pressure of 1.36×10^5 Pa. What is the elevation here? (1.43 m)
18. A 5.40 cm diameter pipe carries water at 3.70 m/s at an elevation of 3.40 m and a pressure of 1.56×10^5 Pa. At an elevation of 4.60 m the pipe narrows to 4.20 cm in diameter. What is the pressure in this part of the pipe? (1.32×10^5 Pa)
19. A 3.50 cm diameter pipe carries water at 4.10 m/s at an elevation of 6.30 m and a pressure of 1.24×10^5 Pa. The pipe widens out at an elevation of 5.10 m where the pressure is 1.43×10^5 Pa. What is the velocity here and the diameter of the pipe? (1.53 m/s and 5.72 cm)
20. Water moves at 4.90 m/s down a 4.70 cm diameter pipe at an elevation of 3.80 m and a pressure of 1.21×10^5 Pa. At a different elevation the pipe widens to 5.90 cm in diameter and is at a pressure of 1.37×10^5 Pa. What is the elevation here? (2.90 m)

Stokes law: $F_D = 6\pi\eta rv$, at terminal velocity = $mg = \rho Vg$.
(Ignore the buoyant force of air, but not the buoyant force of water.)
1 micron = 1×10^{-6} m = 1 μm
Water: $\rho = 1000.\ kgm^{-3}$, $\eta = 1.002 \times 10^{-3}$ Pa s. Air: $\rho = 1.29\ kgm^{-3}$, $\eta = 1.81 \times 10^{-5}$ Pa s at 20 °C

21. A droplet of water is 6.12 μm in diameter. What is its mass? What is its weight? What speed must it fall through air so that its Stokes drag is equal to its weight? (This is its terminal velocity) (1.20×10^{-13} kg, 1.18×10^{-12} N, 0.00113 m/s)
22. A droplet of mist falls through air with a terminal velocity of 0.00156 m/s. What is its radius? (Ignore the buoyant force of the air) (3.60 μm)
23. A tiny grain of basalt ($\rho = 2920\ kgm^{-3}$) is 2.20 microns in diameter. What speed does it settle in water? (Don't ignore the buoyant force of water) (5.05×10^{-6} m/s)
24. A tiny grain of basalt ($\rho = 2920\ kgm^{-3}$) takes 27.0 minutes to settle from the top of a 8.50 cm tall test tube full of water to the bottom. What is its speed? What is its radius? What time would it take to settle in a 5.40 cm radius centrifuge spinning at 1200 RPM? (5.25×10^{-5} m/s, 3.54×10^{-6} m, 18.6 s)
25. A 3.60 micron diameter particle falls through air with a terminal velocity of 0.00130 m/s. What is its density? ($3330\ kgm^{-3}$)

Reynolds number $Re_r = {}^{vr\rho}/_{\eta}$

26. Syrup with a viscosity of 1.20 Pa s and a density of 1080 kgm^{-3} needs to have turbulent flow down a pipe where it is heated. What speed must it go down a pipe that is 68.0 cm in diameter to ensure that it has a Re_r of 1200? (3.92 m/s)
27. What is the Re_r of water flowing at 0.130 m/s down a tube that is 8.01 mm in diameter? (520.)
28. What is the maximum speed air can flow down a 24.0 cm diameter duct to have a Re_r of 850? (9.94 cm/s)
29. What is the Re_r of air flowing at 0.935 m/s down a duct with a diameter of 1.20 m? (4.00×10^4)
30. What maximum diameter pipe can water flow down at 0.890 m/s to have a Re_r of 950? (2.14 mm)