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PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. Simple pendulum 1, of length L_1, has a bob of mass m_1. Simple pendulum 2, of length L_2, has a bob of mass m_2. $L_1 = 2L_2$ and $m_1 = 2m_2$. Which one of the following statements concerning the periods, T_1 and T_2, of the pendula is correct?

(D)

(A) $T_1 = \frac{1}{\sqrt{2}} T_2$
(B) $T_1 = \frac{1}{2} T_2$
(C) $T_1 = T_2$
(D) $T_1 = \sqrt{2}\, T_2$
(E) $T_1 = 2T_2$

$\omega = \frac{2\pi}{T} = \sqrt{\frac{g}{L}}$

$\Rightarrow T = 2\pi\sqrt{\frac{L}{g}}$

$\frac{T_1}{T_2} = \sqrt{\frac{L_1}{L_2}} = \sqrt{\frac{2L_2}{L_2}} = \sqrt{2}$

A2. "Any fluid applies a buoyant force to an object that is partially or completely immersed in it, and the magnitude of the buoyant force equals the weight of the fluid that the object displaces." This statement is known as

(B)

(A) Bernoulli's Principle.
(B) Archimedes' Principle.
(C) Pascal's Principle.
(D) Poiseuille's Law.
(E) the Principle of Superposition.

$P_h = P_{atm} + \rho g h = 1.5 P_{atm}$

$\Rightarrow \rho g h = 0.5 P_{atm}$

$P_{2h} = P_{atm} + \rho g (2h)$
$= P_{atm} + 2(0.5 P_{atm})$
$= 2 P_{atm}$

A3. The absolute pressure at a depth h below the surface of the ocean is $1.5\, P_{atm}$, where P_{atm} is the atmospheric pressure. The absolute pressure at a depth $2h$ is then

(A)

(A) $2\, P_{atm}$ (B) $3\, P_{atm}$ (C) $4\, P_{atm}$ (D) $6\, P_{atm}$ (E) $9\, P_{atm}$

A4. Due to an obstruction, the radius of an artery is reduced to ½ of its unobstructed value. Which one of the following statements is correct concerning the blood flow speed and the pressure in the obstructed region, compared to the unobstructed region? Consider blood to be an ideal fluid, ignore any viscous effects. $A_1 v_1 = A_2 v_2$, $A_2 < A_1 \Rightarrow v_2 > v_1$, $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$ $\Rightarrow P_2 < P_1$

(D)

(A) Both the flow speed and the pressure are decreased in the obstructed region.
(B) Both the flow speed and the pressure are increased in the obstructed region.
(C) The flow speed is decreased and the pressure is increased in the obstructed region.
(D) The flow speed is increased and the pressure is decreased in the obstructed region.
(E) The flow speed is increased and the pressure is unchanged in the obstructed region.

A5. A periodic wave passes an observer, who records that there is a time of 0.5 s between wave crests. Which one of the following statements about the wave is correct?

(C)

(A) The frequency is 0.5 Hz. (B) The speed is 0.5 m/s.
(C) The period is 0.5 s. (D) The amplitude is 0.5 m.
(E) The wavelength is 0.5 m.

continued on page 3 ...

A6. A pressure difference of ΔP is required to maintain a volume flow rate Q, for a liquid of viscosity η, through a pipe of radius R and length L. If the radius of the pipe is reduced to ½ R, the pressure difference required to maintain the same volume flow rate is

(E)

(A) $2\,\Delta P$ (B) $4\,\Delta P$ (C) $6\,\Delta P$ (D) $8\,\Delta P$ (E) $16\,\Delta P$

A7. A soft-drink bottle resonates as air is blown across its top. What happens to the resonant frequency as the level of the fluid in the bottle decreases, and why? Choose the only single answer, where **both the effect and the explanation** are correct.

(A)

(A) The resonant frequency *decreases* because the resonance wavelength of the air column in the bottle *increases*.
(B) The resonant frequency *increases* because the resonance wavelength of the air column in the bottle *increases*.
(C) The resonant frequency *increases* because the resonance wavelength of the air column in the bottle *decreases*.
(D) The resonant frequency *decreases* because the resonance wavelength of the air column in the bottle *decreases*.
(E) The resonant frequency *does not change* because it is independent of the wavelength.

A8. An aviation technician notices that the loudness of the sound from the engines of a twin-engine plane varies with a frequency of 8 Hz when the left engine runs at 9000 rpm making a sound of frequency f_1 = 9000/(60 s) = 150 Hz. As he turns down the speed of the left engine, the frequency of the loudness variations increases. What is the frequency f_2 of the sound from the right engine?

(A)

(A) 158 Hz (B) 150 Hz (C) 142 Hz (D) 166 Hz (E) 154 Hz

$|f_1 - f_2| = 8\text{ Hz} \Rightarrow f_2 = 158\text{ Hz}$ or 142 Hz. But $f_1 < f_2 \Rightarrow f_2 = 158\text{ Hz}$

A9. Suppose we have three identical conducting spheres. One is given a charge Q, the other two are neutral. If they are all brought into contact with each other and then separated, what will be the final result?

Charges distribute uniformly

(B)

(A) They will each have a charge Q.
(B) They will each have a charge $Q/3$.
(C) Only one will have a charge Q, the others will be neutral.
(D) They will all be discharged.
(E) Two will have a charge Q, the other one will have charge $-Q$.

A10. A negatively charged ebonite rod is brought close to an isolated metal sphere, *without* touching it. What happens?

(B)

(A) The negatively charged ebonite rod attracts the negative charges and repels the positive charges in the metal sphere, but the total charge in the metal sphere does not change.
(B) The negatively charged ebonite rod attracts the positive charges and repels the negative charges in the metal sphere, but the total charge in the metal sphere does not change.
(C) The negatively charged ebonite rod induces a negative charge on the metal sphere.
(D) The negatively charged ebonite rod induces a positive charge on the metal sphere.
(E) The negatively charged ebonite rod has no effect whatsoever on the charges in the sphere.

continued on page 4 ...

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PART B

FOR EACH OF THE FOLLOWING PROBLEMS, B1 TO B5, ON PAGES 4 TO 6, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 6.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. A lead brick (density = 11300 kg/m^3) measures 0.200 m by 0.0600 m by 0.0600 m. What volume of water has the same mass as this brick? (Density of water = 1000 kg/m^3)

mass of lead: $m_L = \rho_L V_L$

mass of water: $m_w = \rho_w V_w$

$$m_L = m_w \Rightarrow \rho_w V_w = \rho_L V_L$$

$$\Rightarrow V_w = \frac{\rho_L V_L}{\rho_w}$$

$$= \frac{11300\ \text{kg/m}^3}{1000\ \text{kg/m}^3}(0.200\ \text{m} \times 0.0600\ \text{m} \times 0.0600\ \text{m})$$

$$= 8.14 \times 10^{-3}\ \text{m}^3$$

B2. A mass on the end of an ideal spring is undergoing Simple Harmonic Motion. The amplitude of the motion is 0.250 m and the period is 1.25 s. Given that the mass was at maximum displacement from the equilibrium position when it was released, calculate the speed of the mass 0.686 s after release.

$$v = -A\omega \sin(\omega t) \qquad \omega = \frac{2\pi}{T}$$

$$= -\frac{A\,2\pi}{T}\sin\left(\frac{2\pi}{T}t\right)$$

$$= -\frac{(0.250\ \text{m})\,2\pi}{1.25\ \text{s}}\sin\left(\frac{2\pi\,(0.686\ \text{s})}{1.25\ \text{s}}\right)$$

$$= -1.26\ \text{m/s}\ \sin(3.45\ \text{rad})$$

$$= +0.379\ \text{m/s}$$

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B3. Gasoline flows out of the nozzle of a filling hose at a speed of 1.55 m/s. The nozzle has a cross-sectional area of 3.2×10^{-4} m^2. How long does it take to fill a 70.0 litre tank from this nozzle? (1 m^3 = 1000 litres)

$$Q = Av = \frac{V}{t}$$

$$\Rightarrow t = \frac{V}{Av}$$

$$= \frac{70.0 \text{ litre} \left(\frac{1 \text{ m}^3}{1000 \text{ litre}}\right)}{(3.20 \times 10^{-4} \text{ m}^2)(1.55 \text{ m/s})}$$

$$= 141 \text{ s}$$

B4. A point charge, $q_1 = +6.40$ μC is fixed in space. A second charge, q_2, is placed 2.00 m away from this charge and it is noted that there is force on q_2 towards q_1 with magnitude 0.176 N. Calculate the charge q_2 (including its sign).

q_2 attracted to q_1 $\Rightarrow$ q_2 is negative since q_1 is positive

$$F = \frac{k|q_1 q_2|}{r^2}$$

$$\Rightarrow |q_2| = \frac{Fr^2}{k|q_1|}$$

$$= \frac{(0.176 \text{ N})(2.00 \text{ m})^2}{(9.00 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(6.40 \times 10^{-6} \text{ C})}$$

$$= 1.22 \times 10^{-5} \text{ C}$$

$$= 12.2 \ \mu\text{C}$$

$$\therefore q_2 = -12.2 \ \mu\text{C}$$

continued on page 6 ...

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B5. How close to a proton do you have to get to experience an electric field with a magnitude of 1.00 N/C? (Treat the proton as a point charge.)

$$E = \frac{k|q|}{r^2} = \frac{ke}{r^2} \quad q = +e \text{ for a proton}$$

$$\Rightarrow r = \sqrt{\frac{ke}{E}}$$

$$= \sqrt{\frac{(9.00 \times 10^{9}\ \mathrm{N.m^2/C^2})(1.60 \times 10^{-19}\ \mathrm{C})}{(1.00\ \mathrm{N/C})}}$$

$$= 3.79 \times 10^{-5}\ \mathrm{m}$$

ANSWERS FOR PART B

ENTER THE ANSWERS FOR THE PART B PROBLEMS IN THE BOXES BELOW.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1	$8.14 \times 10^{-3}\ \mathrm{m^3}$
B2	$0.379\ \mathrm{m/s}$
B3	$141\ \mathrm{s}$
B4	$-1.22 \times 10^{-5}\ \mathrm{C} = -12.2\ \mu\mathrm{C}$
B5	$3.79 \times 10^{-5}\ \mathrm{m}$

continued on page 7...

PART C

IN EACH OF THE PART C QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

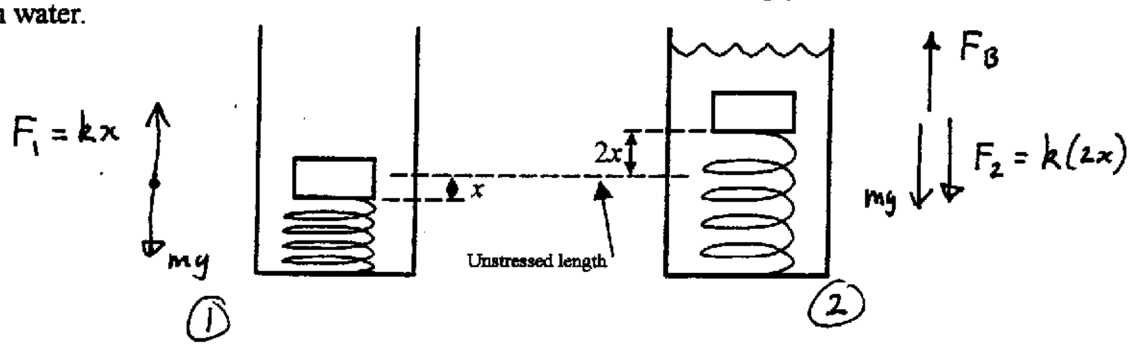
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

SHOW YOUR WORK – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY. EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

C1. A spring is attached to the bottom of a large empty container, with the axis of the spring oriented vertically. A 2.55 kg block is fixed to the top of the spring and compresses it a distance x. The container is now filled with water, completely covering the block. The spring is now observed to be stretched a distance $2x$ from its unstressed length, twice as much as it had been compressed. (Density of water = 1000 kg/m^3)

(a) Show clearly the forces acting on the block when the container is empty, and when it is filled with water.



(b) Calculate the volume of the block.

$\boxed{7.65 \times 10^{-3}\ m^3}$

From (1) $\Sigma F_y = F_1 - mg = 0$ (equilibrium)

$\Rightarrow kx = mg$

From (2) $\Sigma F_y = F_B - mg - F_2 = 0$ (equilibrium)

$\Rightarrow F_B = mg + k(2x) = mg + 2(kx)$

$\Rightarrow \rho_w V g = mg + 2(mg)$ (since $kx = mg$)

$= 3\,mg$

$\Rightarrow V = \dfrac{3m}{\rho_w} = \dfrac{3(2.55\ kg)}{1000\ kg/m^3} = 7.65 \times 10^{-3}\ m^3$

continued on page 8 ...

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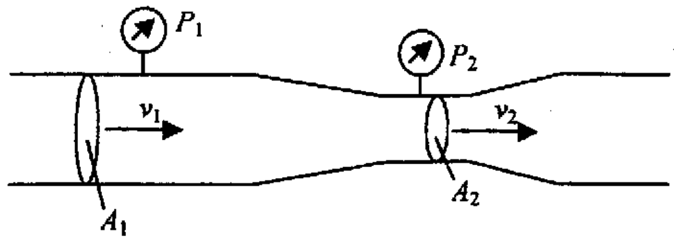
C2. A Venturi meter measures the flow speed of water through a pipe. The speed to be measured is v_1, the speed in the pipe where the cross-sectional area is $A_1 = 4.10 \times 10^{-4}\ \text{m}^2$. Pressure meters measure the pressure in this pipe (P_1), and the pressure (P_2) at a narrow section of pipe with cross-sectional area $A_2 = 3.24 \times 10^{-4}\ \text{m}^2$. Assume water behaves as an ideal, non-viscous fluid. (Density of water is $1000\ \text{kg/m}^3$.)



(a) Derive an expression for v_2, the speed where the cross-sectional area is A_2, in terms of v_1, A_1 and A_2.

$$\boxed{v_2 = \frac{A_1}{A_2} v_1}$$

Continuity equation: $A_1 v_1 = A_2 v_2$

$$\Rightarrow v_2 = \frac{A_1}{A_2} v_1$$

(b) If the pressure difference, $P_1 - P_2$ is measured to be 81.0 Pa, calculate the speed v_1 of the water in the pipe.

$$\boxed{0.519\ \text{m/s}}$$

Bernoulli's Equation:

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2$$

$$\Rightarrow P_1 - P_2 = \tfrac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$= \tfrac{1}{2}\rho\left(\left(\frac{A_1 v_1}{A_2}\right)^2 - v_1^2\right)$$

$$= \tfrac{1}{2}\rho v_1^2\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)$$

$$\Rightarrow v_1^2 = \frac{2(P_1 - P_2)}{\rho\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}$$

$$\Rightarrow v_1 = \sqrt{\frac{2(81.0\ \text{Pa})}{(1000\ \text{kg/m}^3)\left(\left(\frac{4.10\times10^{-4}\ \text{m}^2}{3.24\times10^{-4}\ \text{m}^2}\right)^2 - 1\right)}}$$

$$= 0.519\ \text{m/s}$$

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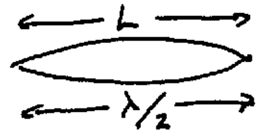
C3. A cello string vibrates in its fundamental mode with a frequency of 220.0 Hz (the note A). The vibrating segment of the string has length 70.0 cm and has mass 1.20 g.

(a) Find the tension in the string.

$\boxed{163\ N}$

$$v = \sqrt{\frac{F}{m/L}} = f\lambda$$



Fundamental: $L = \frac{\lambda}{2} \Rightarrow \lambda = 2L$

$$\Rightarrow \frac{F}{m/L} = f^2(2L)^2$$

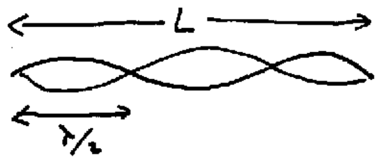
$$\Rightarrow F = 4f^2L^2\frac{m}{L} = 4f^2Lm$$

$$= 4\,(220\ s^{-1})^2(0.700\,m)(1.20\times10^{-3}\,kg) = 163\ N$$

(b) When this string is vibrating in its 3rd harmonic, what is the wavelength of the waves in the string?

$\boxed{0.467\ m}$

3rd harmonic:



$$\Rightarrow L = 3\left(\frac{\lambda}{2}\right)$$

$$\Rightarrow \lambda = \frac{2L}{3} = \frac{2\,(0.700\,m)}{3} = 0.467\ m$$

(c) A finger is pressed on the string to reduce the length of the vibrating segment of the string to a length *x*. The tension in the string remains the same. When this is done the fundamental frequency is 261.63 Hz (the note C). Find the length *x*.

$\boxed{0.589\ m}$

F same and m/L same $\Rightarrow v$ same

$f_1 = 220\ Hz$: $\quad v = f_1\lambda_1 = f_1 2L$ for fundamental

$f_2 = 261.63\ Hz$: $\quad v = f_2 2x$

$$\Rightarrow f_1 2L = f_2 2x$$

$$\Rightarrow x = \frac{f_1 L}{f_2} = \frac{220.0\ Hz}{261.63\ Hz}(0.700\,m) = 0.589\ m$$

END OF EXAMINATION