UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST

February 16, 2017 Time: 90 minutes

NAME: SOLUTIONS
(Last) **Please Print** (Given)

STUDENT NO.: ____________

LECTURE SECTION (please check):

- ❑ 01 Dr. Y. Yao
- ❑ 02 B. Zulkoskey

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card and an OMR sheet. The test paper consists of 8 pages, including this cover page. **It is the responsibility of the student to check that the test paper is complete**.
3. Only a basic scientific calculator (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, are **not** allowed.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

QUESTION NUMBER	MAXIMUM MARKS	MARKS OBTAINED
A1-12	12	
B1-4	8	
B5-8	8	
B9-12	8	
B13-16	8	
MARK	out of 36:	

Physics 117.3 Midterm Test
February 16, 2017

Stu. No.: ______________________

PART A

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

E

A1. Consider two rigid bars. The Young's modulus for bar 1 is twice the Young's modulus for bar 2, i.e. $Y_1 = 2Y_2$. Which one of the following statements must be true?

(A) The cross-sectional area of bar 1 is twice that of bar 2. i.e. $A_1 = 2A_2$
(B) The cross-sectional area of bar 1 is half that of bar 2. i.e. $A_1 = 0.5A_2$
(C) The length of bar 1 is twice that of bar 2. i.e. $L_1 = 2L_2$
(D) The length of bar 1 is half that of bar 2. i.e. $L_1 = 0.5L_2$
(E) The two bars are made of different materials.

Young's modulus is a property of the material.

A

A2. Consider a large rectangular block of wood that has a weight of 1.8×10^4 N and dimensions of 1 m × 2 m × 3m. Which one of the following statements is correct concerning the pressure(s) that the block of wood can exert on a flat horizontal floor?

(A) The pressure exerted by the block can be 9000 Pa, 6000 Pa, or 3000 Pa, depending on its orientation.
(B) The pressure exerted by the block can only be 9000 Pa.
(C) The pressure exerted by the block can only be 6000 Pa.
(D) The pressure exerted by the block can only be 3000 Pa.
(E) The pressure exerted by the flock can be 9000 Pa or 6000 Pa, but not 3000 Pa.

$P = \frac{F}{A}$; $F = 1.8 \times 10^4 N$, $A = 1m \times 2m$; $1m \times 3m$; or $2m \times 3m$, depending on orientation

C

A3. Which one of the following statements best describes the situation in a hydraulic lift?

(A) A small pressure change in a small cylinder produces a large pressure change in a large cylinder.
(B) A small pressure change in a large cylinder produces a large pressure change in a small cylinder.
(C) A small force applied to a small piston produces a large force on a large piston.
(D) A small force applied to a large piston produces a large force on a small piston.
(E) A small displacement of a small piston produces a large displacement of a large piston.

Pascal's Principle: $\Delta P = \Delta F / A$ throughout the system. ∴ If A ↑, so does ΔF.

C

A4. A block on a horizontal frictionless surface is connected to an ideal spring (spring constant k) and moves with simple harmonic motion of amplitude A. At the equilibrium position, the speed of the block is υ. Which one of the following expressions is correct?

$\upsilon = \upsilon_{max} = \omega A = \sqrt{\frac{k}{m}} \cdot A$

(A) $A = 2\upsilon\sqrt{\frac{m}{k}}$ (B) $A = \upsilon\sqrt{\frac{2m}{k}}$ (C) $A = \upsilon\sqrt{\frac{m}{k}}$ (D) $A = \upsilon\sqrt{\frac{m}{2k}}$ (E) $A = \frac{1}{2}\upsilon\sqrt{\frac{m}{k}}$

so $A = \upsilon\sqrt{m/k}$

D

A5. The average radius of a pipeline is reduced by 3.00% due to sludge. If the pressure difference between the two ends of the pipeline remains the same, by what percentage is the volume flow rate of a viscous liquid through the pipeline decreased?

(A) 3.00% (B) 8.10% (C) 9.00% (D) 11.5% (E) 81.0%

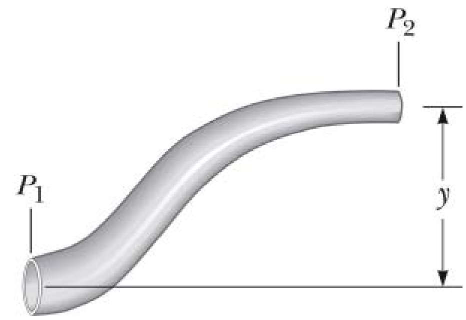
Poiseuille's Law: $\frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L} \Rightarrow \frac{\Delta V}{\Delta t} \propto R^4$ $R_2 = 0.97 R_1$ (3% decrease)

$\frac{(\Delta V/\Delta t)_2}{(\Delta V/\Delta t)_1} = \frac{R_2^4}{R_1^4} = \frac{(0.97R_1)^4}{R_1^4} = 0.885 \Rightarrow \left(\frac{\Delta V}{\Delta t}\right)_2 = 0.885\left(\frac{\Delta V}{\Delta t}\right)_1 \Rightarrow$ 11.5% decrease

A6. Water moves through the pipe shown below in steady, ideal flow. Region 2 is higher than region 1 and the cross-sectional area at region 2 is less than at region 1.

C

$A_1 v_1 = A_2 v_2 \Rightarrow v_2 > v_1$ because $A_2 < A_1$



$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

$v_2 > v_1$, $y_2 > y_1 \Rightarrow P_2 < P_1$

Which one of the following statements is correct concerning the pressure and flow speed in region 2 compared to region 1?

(A) Both the pressure and flow speed are higher in region 2 than in region 1.
(B) Both the pressure and flow speed are lower in region 2 than in region 1.
(C) The pressure is lower in region 2 but the flow speed is higher than in region 1.
(D) The pressure is higher in region 2 but the flow speed is lower than in region 1.
(E) The pressure is lower in region 2 than in region 1 but the flow speed is the same.

A7. A father and daughter are swinging on adjacent swings with chains of the same length *L*. The daughter's mass is *m* and the maximum deflection angle of her swing is 4°. The father's mass is 4*m* and the maximum deflection angle of his swing is 8°. Each swing can be treated as a simple pendulum. If the period for the daughter's motion is *T*, the period for the father's motion is…

C

(A) 2 *T* (B) 1.41 *T* (C) *T* (D) 0.5 *T* (E) 0.25 *T* $T = 2\pi\sqrt{\frac{L}{g}}$

no dependence of T on m or θ_{max}

A8. By how much does the decibel level change when you increase your distance from a sound source by a factor of 10, and the power output from the source also increases by a factor of 10?

B

(A) 10 dB increase (B) 10 dB decrease (C) no change
(D) 100 dB decrease (E) 20 dB increase

$I \propto \frac{1}{r^2}$; $I \propto P$

$\therefore I_2 = \left(\frac{1}{10^2}\right) 10 \times I_1 = \frac{1}{10} I_1$

$\therefore \beta_2$ is 10dB less than β_1

A9. Which one of the following is **not** an example of a transverse wave/oscillation?

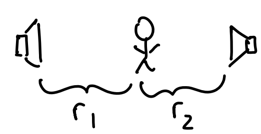
A

(A) a sound wave in air longitudinal wave
(B) the electric field component of an electromagnetic wave
(C) the magnetic field component of an electromagnetic wave
(D) the wave on a stretched string such as the one that was examined in lab S1
(E) the wave on a guitar string

A10. A person stands exactly halfway between two speakers, with one speaker on his left and one on his right. Both speakers are playing identical, in phase, single-frequency sound and the person detects constructive interference of the sound waves. How far to his left should the person move to be at the next position of constructive interference? The wavelength of the sound is λ.

C

(A) one-eighth λ (B) one-quarter λ (C) one-half λ
(D) λ (E) three-eighths λ



For constructive interference, $r_2 - r_1 = n\lambda = 0, \lambda, 2\lambda, \ldots$

Initially, $r_1 = r_2$. movement of Δx to left: $r_2' - r_1' = r_2 + \Delta x - (r_1 - \Delta x) = 2\Delta x$

$\therefore$ $2\Delta x = \lambda$ for next position of constructive interference $\Rightarrow \Delta x = \frac{1}{2}\lambda$

A11. Which one of the following regions of the electromagnetic spectrum has the highest frequencies?

B

(A) visible light (B) X-rays (C) radio waves
(D) ultraviolet (E) microwaves

A12. Which one of the following statements regarding electromagnetic (EM) waves travelling through a vacuum is true?

E

(A) All EM waves have the same wavelength. F
(B) All EM waves have the same frequency. F
(C) The waves have different speeds, which depend inversely on frequency. F (speed = c)
(D) The electric and magnetic fields associated with the waves have fixed magnitudes. F
(E) The electric and magnetic fields associated with the waves are perpendicular to each other and to the direction of propagation of the wave. T

PART B

WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.

WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).

IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE HALF-MARKS (1/2).

IF YOU STILL DO NOT HAVE THE CORRECT ANSWER, BUT REWORK YOUR SOLUTION AND REVEAL A STAR WITH YOUR THIRD SCRATCH, THEN YOU RECEIVE 0.2/2.

REVEALING THE STAR WITH YOUR FOURTH OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

YOU MAY ANSWER ALL FOUR PART B QUESTION GROUPINGS (1-4, 5-8, 9-12, AND 13-16) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 3 GROUPINGS.

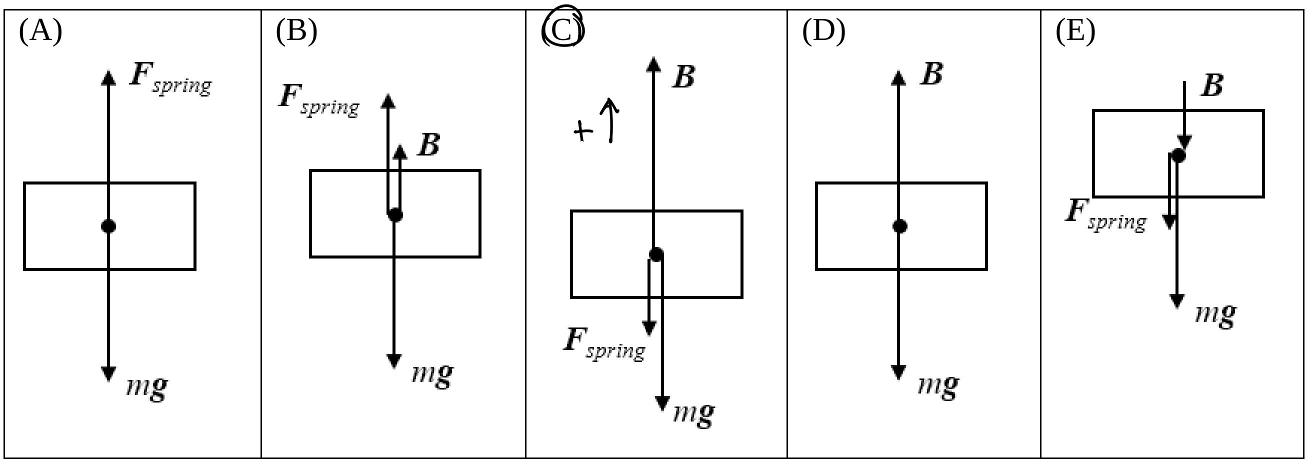
USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

B1. One end of a vertical spring is attached to the bottom of the inside of a pail. An object of mass 453 g is attached to the other end of the spring. The spring constant is 67.8 N/m and the density of the object is 802 kg/m^3. The pail is now filled with water until the object is completely submerged. The density of water is 1.00×10^3 kg/m^3. When the object is completely submerged…

(A) the spring is stretched.
(B) the spring is relaxed – neither compressed nor stretched.
(C) the spring is compressed more than when the pail was empty.
(D) the spring is compressed, but not as much as when the pail was empty.
(E) the state of the spring cannot be determined without more information.

$\rho_{obj} < \rho_{water}$, $\therefore B > mg$, object tries to float, $\therefore$ spring stretches to keep the object completely submerged.

B2. Which one of the following is the correct free-body diagram for the object when it is completely submerged?



B3. Calculate the magnitude of the buoyant force on the object when it is completely submerged.

$$B = \rho_f V_f g = \rho_f V_{obj} g = \rho_f \frac{M_{obj}}{\rho_{obj}} g = (1.00 \times 10^3 \text{ kg/m}^3)\left(\frac{0.453 \text{ kg}}{802 \text{ kg/m}^3}\right)(9.80 \text{ m/s}^2)$$
$$= 5.535 \text{ N} = 5.54 \text{ N}$$

B4. Calculate the displacement of the object from the equilibrium position when the object is completely submerged.

$$\sum \vec{F} = 0 \text{ for object} \Rightarrow B - F_{spring} - mg = 0 \Rightarrow B - kx - mg = 0$$

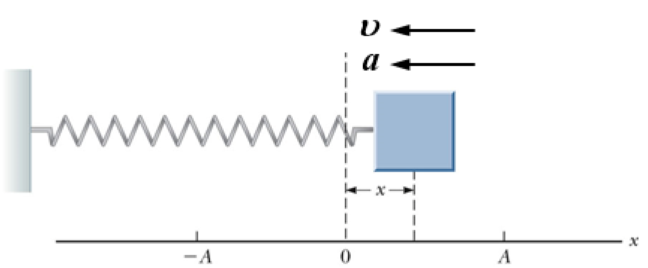
$$x = \frac{B - mg}{k} = \frac{5.535 \text{ N} - (0.453 \text{ kg})(9.80 \text{ m/s}^2)}{67.8 \text{ N/m}} = 0.0162 \text{ m} = 1.62 \text{ cm}$$

B5. A 0.250-kg block resting on a frictionless, horizontal surface is attached to a spring that has a spring constant of 83.8 N/m. An externally-applied horizontal force $\vec{F}$ causes the spring to stretch a distance of 5.46 cm from its equilibrium position. Calculate the value of $\vec{F}$.

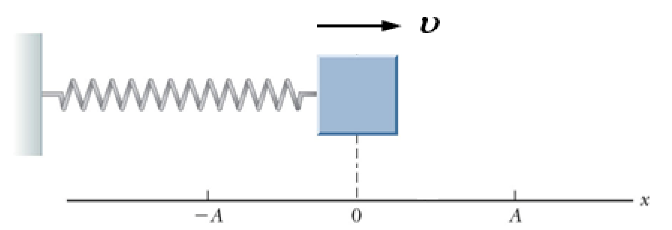
$$F = |kx| = (83.8\,N/m)(0.0546\,m) = 4.575\,N = 4.58\,N$$

B6. After the externally-applied force is removed, the block oscillates with simple harmonic motion. Which one of the following diagrams is **not physically possible** regarding the velocity $\vec{v}$ and acceleration $\vec{a}$ of the block?

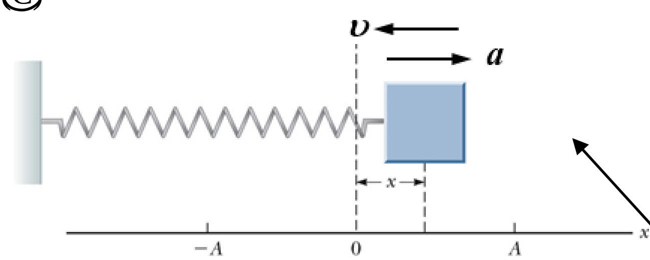
(A)



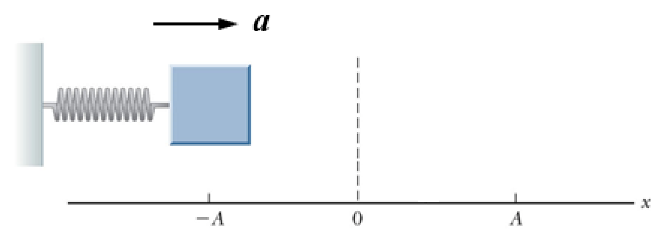
(B)



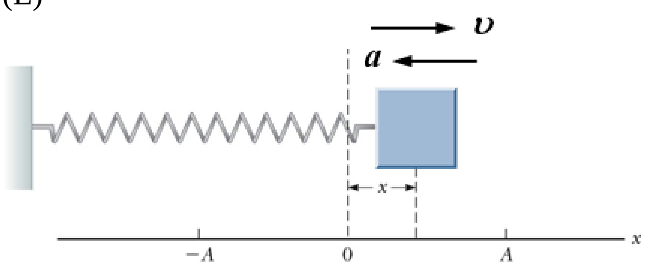
(C)



(D)



(E)



not physically possible because $\vec{a}$ is always directed opposite to $\vec{x}$

B7. Calculate the total energy of the block-spring system.

$$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}mv_{max}^2 = \frac{1}{2}kA^2$$

$$A = 5.46\,cm = 0.0546\,m \;;\quad E = \frac{1}{2}(83.8\,N/m)(0.0546\,m)^2$$

$$\boxed{E = 0.125\,J}$$

Stu. No.: ______________________

B8. Calculate the speed of the block when it is at $x = A/2$.

Energy is conserved, so $\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = E$

$$\frac{1}{2}mv^2 = E - \frac{1}{2}kx^2 \quad \text{where } x = \frac{A}{2} = \frac{0.0546\text{m}}{2} = 0.0273\text{ m}$$

$$v = \sqrt{\frac{2}{m}\left(E - \frac{1}{2}kx^2\right)}$$

$$v = \sqrt{\frac{2}{0.250\text{kg}}\left(0.125\text{J} - \frac{1}{2}(83.8\text{N/m})(0.0273\text{m})^2\right)} = 0.866\text{ m/s}$$

A police cruiser travelling east at a speed of 126.0 km/h is chasing a car, also travelling east, that is moving at a speed of 141.0 km/h. The police cruiser's siren is emitting sound of frequency *f*s = 3450 Hz. The speed of sound is 343 m/s = 1235 km/h.

. . .

$|v_o| > |v_s| \Rightarrow$ observer is getting further away from the source $\Rightarrow f_o < f_s$

B9. Which one of the following statements is correct?

(A) The driver of the car being chased hears a siren frequency > *fs* and the officer in the cruiser hears a siren frequency < *fs*.
(B) The driver of the car being chased hears a siren frequency < *fs* and the officer in the cruiser hears a siren frequency > *fs*.
(C) The driver of the car being chased hears a siren frequency < *fs* and the officer in the cruiser hears a siren frequency < *fs*.
(D) The driver of the car being chased hears a siren frequency < *fs* and the officer in the cruiser hears a siren frequency of *fs*.
(E) The driver of the car being chased hears a siren frequency > *fs* and the officer in the cruiser hears a siren frequency of *fs*.

B10. Calculate the frequency of the siren sound heard by the drive of the car being chased.

$$f_o = \left(\frac{v+v_o}{v-v_s}\right) f_s = \left(\frac{1235\text{ km/h} + (-141\text{ km/h})}{1235\text{ km/h} - (+126\text{ km/h})}\right)(3450\text{ Hz})$$

observer moving away $\Rightarrow v_o$ −ve

source moving toward $\Rightarrow v_s$ +ve

$$\boxed{f_o = 3403\text{ Hz}}$$

B11. Realizing that the car being chased is getting away, the office in the cruiser radios ahead for a road block. Calculate the siren frequency heard by an officer at the stationary road block that is to the east of the cruiser.

Now $v_o = 0$ (stationary observer at road block)

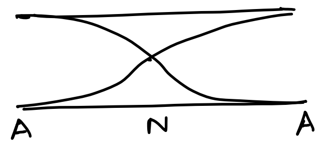
$v_s = +126$ km/h (source moving toward)

$$f_o = \left(\frac{v+v_o}{v-v_s}\right) f_s = \left(\frac{1235\text{ km/h} + 0}{1235\text{ km/h} - 126\text{ km/h}}\right)(3450\text{ Hz}) = 3842\text{ Hz}$$

B12. The siren is producing sound energy uniformly in all directions at a rate of 165 W. Calculate the intensity of the siren sound at the road block when the approaching cruiser is 1.00 km away.

$$I = \frac{P}{A} = \frac{P}{\underbrace{4\pi r^2}_{\text{spherical wavefronts}}} = \frac{165\text{ W}}{4\pi(1.00\times10^3\text{ m})^2} = 1.31\times10^{-5}\text{ W/m}^2$$

A pipe of length L is open at both ends. The pipe is made to go into resonance at its fundamental frequency, $f_{1,\text{open}}$. The speed of sound in air is υ.



$A\text{-}A = \frac{1}{2}\lambda_1$

$\Downarrow$

$L = \frac{1}{2}\lambda_1$

$\lambda_1 = 2L$

B13. Which one of the following is the correct expression for $f_{1,\text{open}}$?

(A) $f_{1,\text{open}} = \dfrac{3\upsilon}{4L}$ (B) $f_{1,\text{open}} = \dfrac{3\upsilon}{2L}$ (C) $f_{1,\text{open}} = \dfrac{\upsilon}{L}$

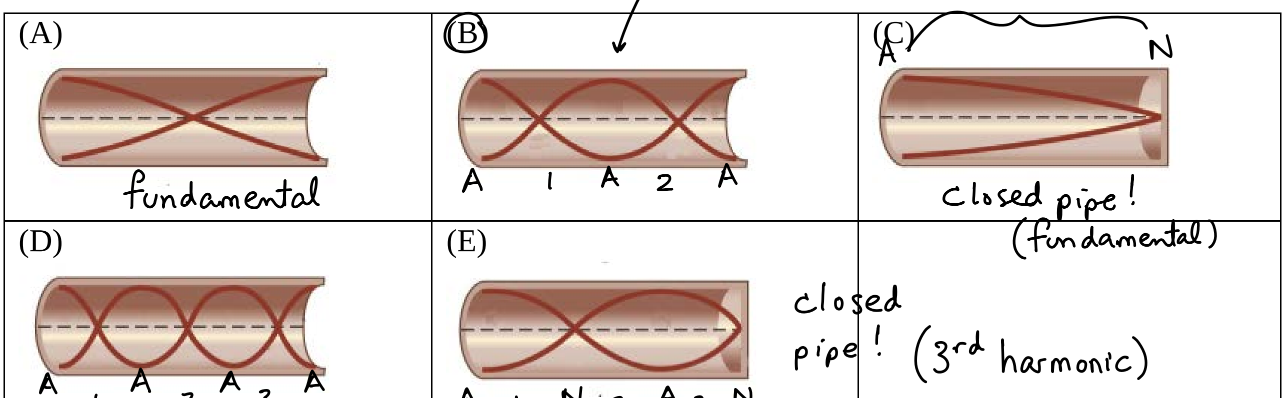
(D) $f_{1,\text{open}} = \dfrac{\upsilon}{2L}$ (E) $f_{1,\text{open}} = \dfrac{\upsilon}{4L}$

$f_1 = \dfrac{\upsilon}{\lambda_1} = \dfrac{\upsilon}{2L}$

B14. Which one of the following is the correct diagram for the second harmonic, $f_{2,\text{open}}$, when the pipe is open at both ends?

B

second harmonic $\frac{1}{4}\lambda = L$



$\Rightarrow$ 3rd harmonic

B15. One end of the pipe is now closed and the pipe is again made to go into resonance at its fundamental frequency $f_{1,\text{closed}}$. Which one of the following expressions correctly describes the relationship between $f_{1,\text{open}}$ and $f_{1,\text{closed}}$?

from diagram (C) above, $L = \frac{1}{4}\lambda_1 \Rightarrow \lambda_1 = 4L$

(A) $f_{1,\text{open}} = 0.67\, f_{1,\text{closed}}$ (B) $f_{1,\text{open}} = f_{1,\text{closed}}$ (C) $f_{1,\text{open}} = 0.5\, f_{1,\text{closed}}$

(D) $f_{1,\text{open}} = 1.5\, f_{1,\text{closed}}$ (E) $f_{1,\text{open}} = 2\, f_{1,\text{closed}}$

$\therefore f_{1,\text{closed}} = \dfrac{\upsilon}{4L} = \dfrac{1}{2}\left(\dfrac{\upsilon}{2L}\right)$

$f_{1,\text{closed}} = \frac{1}{2} f_{1,\text{open}} \Rightarrow f_{1,\text{open}} = 2 f_{1,\text{closed}}$

B16. For the pipe closed as in B15, the third harmonic frequency, $f_{3,\text{closed}}$, is 6.00×10^2 Hz. Calculate the length of the pipe. The speed of sound is 343 m/s.

From diagram (E) of B14, $L = \frac{3}{4}\lambda_3 \Rightarrow \lambda_3 = \frac{4}{3}L$

$$f_{3,\text{closed}} = \frac{\upsilon}{\lambda_3} = \frac{\upsilon}{\frac{4}{3}L} = \frac{3\upsilon}{4L} \Rightarrow L = \frac{3\upsilon}{4f_{3,\text{closed}}} = \frac{3(343\ \text{m/s})}{4(600\ \text{Hz})}$$

$\boxed{L = 0.429\,\text{m}}$

END OF EXAMINATION