PART A

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

A1. Which one of the following statements is true concerning an object executing simple harmonic motion?

D

- (A) Its velocity is never zero.
- (B) Its acceleration is never zero.
- (C) Its velocity and acceleration are zero simultaneously.
- (D) Its velocity is zero when its acceleration is a maximum.
- (E) Its maximum acceleration is equal to its maximum velocity.

A2. The end of a car radio antenna is oscillating back and forth in simple harmonic motion. The amplitude of the oscillation is A and the frequency is f. The magnitude of the maximum acceleration is given by

$$a_{max} = A\omega^2 \quad \omega = 2\pi f$$
$$= A4\pi^2 f^2$$

B

- (A) $2\pi f^2 A$
- (B) $4\pi^2 f^2 A$
- (C) $4\pi^2 f^2 A^2$
- (D) $4\pi f A^2$
- (E) $2\pi f A$.

A3. Which one of the following statements is true for a completely enclosed fluid?

C

- (A) Any change in pressure applied to the fluid produces a change in pressure elsewhere in the fluid which depends on direction.
- (B) The pressure at all points in a fluid is independent of any pressure applied to it.
- (C) Any change in applied pressure produces an equal change in pressure at all points within the fluid.
- (D) An increase in pressure in one part of the fluid results in an equal decrease in pressure in another part of the fluid.
- (E) The pressure is the same at all points within the fluid.

A4. Bernoulli's Principle is a statement of

A

- (A) energy conservation in dynamic fluids.
- (B) momentum conservation in dynamic fluids.
- (C) hydrostatic equilibrium.
- (D) thermal equilibrium in fluids.
- (E) mechanical equilibrium in fluids.

A5. A pressure difference is maintained between two ends of a pipe of length L, and radius R, so that a viscous fluid flows from one end to the other with a flow rate Q. If the length of the pipe is increased by a factor of 16, what must the new radius of the pipe be to obtain the same flow rate Q?

C

- (A) R/4
- (B) R/2
- (C) 2R
- (D) 4R
- (E) 8R

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8\eta L} = \frac{\pi R_2^4 (P_2 - P_1)}{8\eta 16 L}$$
$$\Rightarrow R^4 = \frac{R_2^4}{16}$$
$$\Rightarrow R_2 = \sqrt[4]{16}\, R$$
$$= 2R$$

continued on Page 3...

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A6. The tension in a taut rope is increased by a factor of 9. How does the speed of wave pulses on the rope change, if at all?

(A) The speed remains the same.
(B) The speed is reduced by a factor of 3.
(C) The speed is reduced by a factor of 9.
(D) The speed is increased by a factor of 3.
(E) The speed is increased by a factor of 9.

D

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

$v_2 = \sqrt{\frac{9F}{m/L}} = 3\sqrt{\frac{F}{m/L}} = 3v$

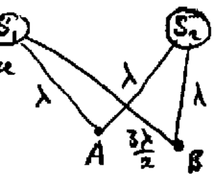
A7. Which of the following superpositions will result in beats?

(A) The superposition of waves that travel with different speeds.
(B) The superposition of identical waves that travel in the same direction.
(C) The superposition of identical waves that travel in the opposite direction.
(D) The superposition of waves that are identical except for slightly different amplitudes.
(E) The superposition of waves that are identical except for slightly different frequencies.

E

A8. Audio sound waves of the same wavelength λ are emitted from two speakers that are vibrating in phase. The speakers are producing sound energy at the same rate and emitting sound uniformly in all directions. Listener A is sitting at a distance λ from each of the speakers. Listener B is sitting at a distance of 3λ/2 from one of the speakers and a distance λ from the other speaker. Which one of the following statements is correct?

Path difference for A = 0 constructive
for B = λ/2 destructive



(A) Both listeners hear sound of the same loudness.
(B) Listener B hears sound that is slightly louder than that heard by listener A.
(C) Listener B hears sound that is much louder than that heard by listener A.
(D) Listener A hears sound that is much louder than that heard by listener B.
(E) The relationship between the loudness of sound heard by the listeners depends on the speed of sound.

D

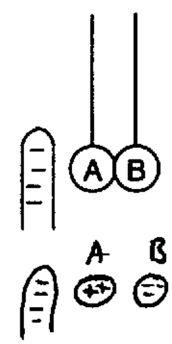
A9. Two conducting spheres, A and B, of equal size are placed on an insulating table. Sphere A has a charge of +Q and sphere B has a charge of –2Q. The spheres are allowed to touch each other and are then separated on the insulating table. Which one of the following statements is correct?

(A) The spheres now each carry a charge of –Q and repel each other.
(B) The spheres now each carry a charge of +3Q/2 and attract each other.
(C) The spheres now each carry a charge of –Q/2 and attract each other.
(D) The spheres now each carry a charge of –Q/2 and repel each other.
(E) Sphere A is now uncharged and sphere B has a charge of –Q.

D

+Q A B −2Q
total charge = +Q + −2Q = −Q
Shared equally
$-\frac{Q}{2}$ $-\frac{Q}{2}$

A10. Two uncharged conducting spheres, A and B, are suspended from insulating threads so that they touch each other. While a negatively-charged rod is held near, but not touching, sphere A, the two spheres are separated. How will the spheres be charged, if at all?



(A) Sphere A will be uncharged and sphere B will be positively charged.
(B) Sphere A will be negatively charged and sphere B will be positively charged.
(C) Both spheres will be uncharged.
(D) Sphere A will be negatively charged and sphere B will be uncharged.
(E) Sphere A will be positively charged and sphere B will be negatively charged.

E

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. How long must a pendulum be if it is to have a period of 10.0 s?

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

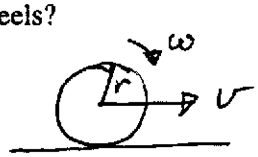
$$\Rightarrow \frac{4\pi^2}{T^2} = \frac{g}{L}$$

$$\Rightarrow L = \frac{gT^2}{4\pi^2}$$

$$= \frac{(9.80\ m/s^2)(10.0\ s)^2}{4\pi^2}$$

$$= 24.8\ m$$

B2. A girl is riding a moped at a constant speed of 14.0 m/s. The wheels of the moped have a radius of 0.230 m and each has a moment of inertia of 0.180 kg.m^2. What is the rotational kinetic energy of <u>one</u> of the wheels?



Rolling without slipping

$\therefore v = r\omega$

Rotational KE $= \frac{1}{2} I \omega^2$

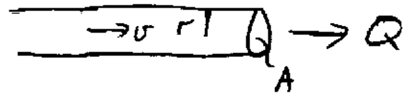
$$= \frac{1}{2} I \left(\frac{v}{r}\right)^2$$

$$= \frac{1}{2}(0.180\ kg.m^2)\left(\frac{14.0\ m/s}{0.230\ m}\right)^2$$

$$= 333\ J$$

continued on page 5 ...

B3. Water flows with a volume flow rate of 1.00 m^3/s in a pipe. Calculate the water speed where the pipe radius is 0.125 m.

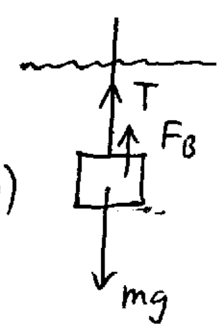


$$Q = Av$$
$$= \pi r^2 v$$
$$\Rightarrow v = \frac{Q}{\pi r^2}$$
$$= \frac{(1.00\ m^3/s)}{\pi\,(0.125\,m)^2}$$
$$= 20.4\ m/s$$

B4. An ancient statue is being salvaged from the bottom of the ocean by being lifted with a cable. The mass of the statue is 70.0 kg and its volume is $3.00 \times 10^{-2}\ m^3$. Half way to the surface the lifting is stopped temporarily. Calculate the tension in the cable as the statue, still fully submerged, is suspended motionless from the cable. The density of sea water is 1024 kg/m^3.

FBD

$(a=0)$



$$\Sigma F = T + F_B - mg = 0$$
$$F_B = \rho V g$$
$$\Rightarrow T = mg - F_B$$
$$= mg - \rho V g$$
$$= (m - \rho V) g$$

$$T = (70.0\,kg - (1024\,kg/m^3)(3.00\times10^{-2}\,m^3))\,(9.80\,m/s^2)$$
$$= 385\ N$$

continued on page 6 ...

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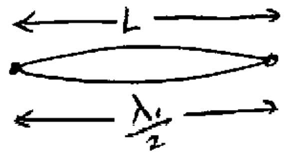
B5. A guitar string of length 0.628 m, fixed at both ends, has a linear mass density (*m/L*) of 5.28×10^{-3} kg/m. Calculate the tension that must be applied to the string to obtain a fundamental frequency of 165 Hz.

Fundamental



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

$\Rightarrow \lambda_1 = 2L$

$$v = f_1 \lambda_1 = \sqrt{\frac{F}{m/L}}$$

$$\Rightarrow f_1 2L = \sqrt{\frac{F}{m/L}}$$

$$\Rightarrow f_1^2 4L^2 = \frac{F}{(m/L)}$$

$$\Rightarrow F = 4 f_1^2 L^2 (m/L)$$

$$= 4 (165\ s^{-1})^2 (0.628\ m)^2 (5.28 \times 10^{-3}\ kg/m)$$

$$= 227\ N$$

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	24.8 m
B2	333 J
B3	20.4 m/s
B4	385 N
B5	227 N

continued on page 7 ...

Student No.: ____________________

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.

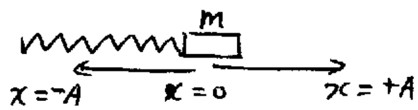
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

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 0.500 kg air-track glider is attached to the end of the track by a horizontal coil spring having a spring constant of 20.0 N/m. Let $x = 0$ be the equilibrium position of the glider. The glider is displaced 0.150 m in the $+x$ direction from its equilibrium position and released so that it oscillates back and forth on the track with a period T (ignore friction).

(a) Calculate the position of the glider at time $t = \frac{T}{8}$.



$A = 0.150\,m$

$\omega = 2\pi f = \frac{2\pi}{T}$

$\boxed{+0.106\ m}$

$x = A \cos \omega t$

at $t = \frac{T}{8}$ $\quad x = A \cos\left(\frac{2\pi}{T}\frac{T}{8}\right)$

$= A \cos(\pi/4)$

$= (0.150\,m) \cos\left(\frac{\pi}{4}\,rad\right)$

$= 0.106\,m$

(b) Calculate the acceleration of the glider at the same time $t = \frac{T}{8}$.

$\boxed{-4.24\ m/s^2}$

$a = -A\omega^2 \cos \omega t$

$\omega = \sqrt{\frac{k}{m}}$

at $t = \frac{T}{8}$ $\quad a = -A\frac{k}{m} \cos\left(\frac{2\pi}{T}\frac{T}{8}\right)$

$= -(0.150\,m)\frac{(20.0\,N/m)}{(0.500\,kg)} \cos(\pi/4)$

$= -4.24\,m/s^2$

continued on page 8 ...

C2. A bicycle and a car have the same speed v_c and are moving away from each other. The car emits a sound of frequency f and the cyclist hears the sound with frequency f'.
The speed of sound in air is v.

(a) Derive an expression which gives the speed v_c in terms of v, f and f'.

$$\boxed{v_c = v\left(\frac{f-f'}{f+f'}\right)}$$

$$f' = f\left[\frac{1 \pm v_o/v}{1 \mp v_s/v}\right]$$

moving away
∴ use lower signs
$v_o = v_s = v_c$

$$\Rightarrow f' = f\,\frac{(1 - v_c/v)}{(1 + v_c/v)}$$

$$\Rightarrow f'(1 + v_c/v) = f(1 - v_c/v)$$

$$\Rightarrow f' + f' v_c/v = f - f\frac{v_c}{v}$$

$$\Rightarrow f\frac{v_c}{v} + f'\frac{v_c}{v} = f - f'$$

$$\Rightarrow \frac{v_c}{v}(f + f') = (f - f')$$

$$\Rightarrow \frac{v_c}{v} = \frac{(f - f')}{(f + f')}$$

$$\Rightarrow v_c = v\left(\frac{f - f'}{f + f'}\right)$$

(b) The speed of sound in air is 343 m/s. The sound emitted by the car has a frequency of 409 Hz and the sound heard by the cyclist has a frequency of 387 Hz. Using your result from part (a), calculate the speed at which the two vehicles are moving.

$$\boxed{9.48 \text{ m/s}}$$

$$v_c = v\left(\frac{f - f'}{f + f'}\right)$$

$$= (343 \text{ m/s})\left(\frac{409 \text{ Hz} - 387 \text{ Hz}}{409 \text{ Hz} + 387 \text{ Hz}}\right)$$

$$= 9.48 \text{ m/s}$$

continued on page 9 ...

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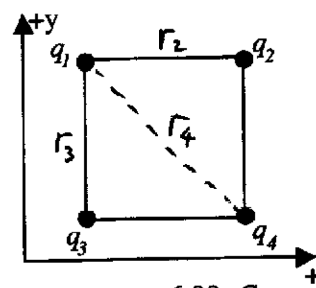
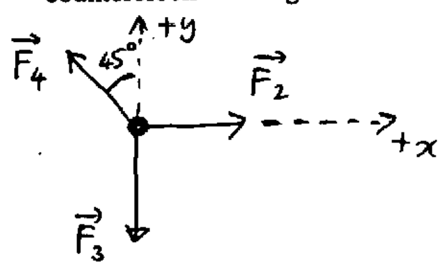
C3. Four charges, each of magnitude 6.00 μC (two positive and two negative), are arranged at the corners of a square as shown. The sides of the square have length 1.00 m. Calculate the electric force (magnitude and direction) acting on the charge q_1 in the upper left corner. Specify the direction as the counterclockwise angle from the +x axis direction.



$q_1 = q_4 = -6.00\mu C$

$q_2 = q_3 = +6.00\mu C$

Magnitude:	0.296 N
Direction:	315 °



$$r_4^2 = (1.00\,m)^2 + (1.00\,m)^2$$
$$r_4 = \sqrt{2}\ m$$

$$F_4 = \frac{k|q_1 q_4|}{r_4^2}$$
$$= \frac{(9.00\times10^9\,N\cdot m^2/C^2)(6.00\times10^{-6}\,C)^2}{(\sqrt{2}\ m)^2}$$
$$= 0.1620N$$

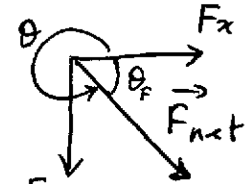
$$F_2 = \frac{k|q_1 q_2|}{r_2^2} = \frac{(9.00\times10^9\,N\cdot m^2/C^2)(6.00\times10^{-6}\,C)^2}{(1.00\,m)^2}$$
$$= 0.3240N$$

$$F_3 = \frac{k|q_1 q_3|}{r_3^2} = 0.3240N$$

$$\vec{F}_{net} = \vec{F}_4 + \vec{F}_2 + \vec{F}_3$$

$$F_x = F_{4x} + F_{2x} + F_{3x}$$
$$= -F_4 \sin 45° + F_2 + 0$$
$$= -0.162N \sin 45° + 0.324\,N$$
$$= 0.2094N$$

$$F_y = F_{4y} + F_{2y} + F_{3y}$$
$$= F_4 \cos 45° + 0 - F_3$$
$$= 0.162N \cos 45° - 0.324N$$
$$= -0.2094N$$



$$F_{net} = \sqrt{F_x^2 + F_y^2}$$
$$= 0.296\,N$$

$$\tan\theta_F = \left|\frac{F_y}{F_x}\right| = 1$$
$$\Rightarrow \theta_F = 45.0°$$
$$\therefore\ \theta = 360° - 45.0°$$
$$= 315°$$

END OF EXAMINATION