PHYS 124 Section A01
Final Examination
Autumn 2006

Name :______**SOLUTIONS**__________

Student ID Number :____________________

Instructor : Marc de Montigny
Time : Monday, December 18, 2006
9:00 – 11:00 AM
Room : Tory Lecture (Turtle) TL-B2

Instructions :

- This booklet contains 12 pages (including 1 blank sheet at the back).
- Items allowed : pen or pencil, calculator (programmable or graphic allowed). Personal digital assistants not allowed.
- Please turn off your cell phones.
- This is a closed-book exam. You may use the formula sheet provided previously, with your own hand-written modifications. Specific rules have been explained in class. You may lose up to 10 marks (out of 45) if :
  1. solutions are included, of if
  2. the formula sheet is not returned with your exam.
- The exam is worth 45% of the course's final score. You can obtain a **maximum of 120 marks** out of the possible **140 marks**.
- The exam contains two sections : Multiple-Choice Questions and Problems
  - o **13 Multiple-Choice Questions**. Not all questions have the same worth in marks. The **total is 50 marks**. No partial marks are given. Circle the one best answer.
  - o **6 Problems**. They are worth a **total of 90 marks**. Partial marks will be given. Show all work clearly and neatly. If you miss a result for a subsequent part of a question, then work algebraically. Please box your answers.
- You may use the back of pages for your own calculations. These will not be marked, unless you specify otherwise.
- When the exam is over, please stop writing immediately, or you may lose marks. Do not discuss with anyone while you are turning it in. Examination rules apply until you have left the exam room.

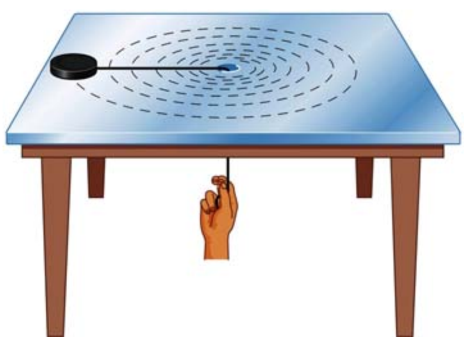
<u>Multiple-Choice Questions (Total of 50 marks).</u> Circle the <u>one</u> best answer.

MC-1. (3 marks) A baseball pitching machine of mass M (including the mass m of the baseball) rests on the pitcher's mound. What is the speed of recoil of the machine when it fires the baseball horizontally at speed v ?

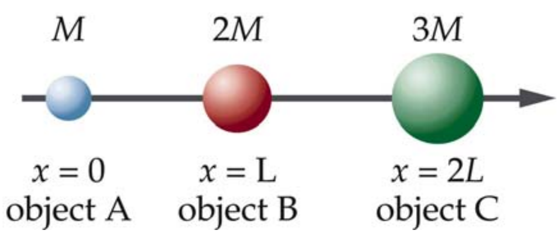
A. $mv/(M-m)$
B. $mv/(M+m)$
C. mv/M
D. $2mv/(M-m)$

MC-2. (3 marks) A puck on a horizontal, frictionless surface is attached to a string that passes through a hole in the surface, as shown below. As the puck rotates, the string is pulled downward, bringing the puck closer to the hole. During this process, does the puck's angular speed

A. decrease,
B. stay the same,
C. increase, or
D. we do not have the appropriate information to answer.



MC-3. (5 marks) Rank the three objects shown below in increasing order of the net gravitational force Gm_1m_2/r^2 each object experiences.



A. $A<B<C$
B. $A<C<B$
C. $C<A<B$
D. None of the above

MC-4. (4 marks) If a projectile is launched vertically from the Earth's surface with a speed equal to the escape speed $v_e = \sqrt{\dfrac{2GM_E}{R_E}}$, how far from the Earth's centre will it be when its speed is half the escape speed ?

A. $2R_E$

B. $\sqrt{2}\,R_E$

C. $4R_E$

D. None of the above

MC-5. (3 marks) The velocity of an object undergoing simple harmonic motion is described by $v = -C\sin(Dt)$. What are the amplitude and period of this object's motion?

A. Amplitude C, period D

B. Amplitude C/D, period $2\pi/D$

C. Amplitude $-C/D$, period $2\pi/D$

D. Amplitude C, period $2\pi/D$

MC-6. (4 marks) A grandfather clock keeps correct time at sea level. If the clock (seen as a simple pendulum) is taken to the top of a nearby mountain, where the acceleration due to gravity is smaller, will the clock

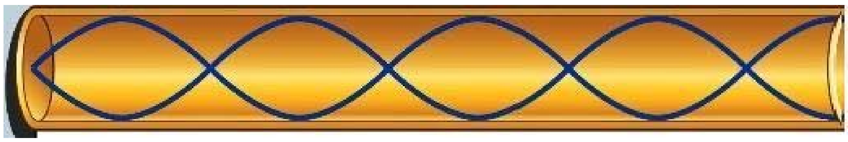
A. run slow,

B. cease functioning,

C. run fast, or

D. keep correct time ?

MC-7. (3 marks) The figure below shows a standing wave in a pipe closed at one end only.



By which factor is the frequency f_n of this harmonic greater than the fundamental frequency f_1 ?

A. One

B. Four

C. Five

D. Nine

MC-8. (5 marks) The frequencies of two successive harmonics in a pipe are 255 Hz and 425 Hz, respectively. Assuming that the speed of sound in this pipe is 340 m/s, what is the length of the pipe?

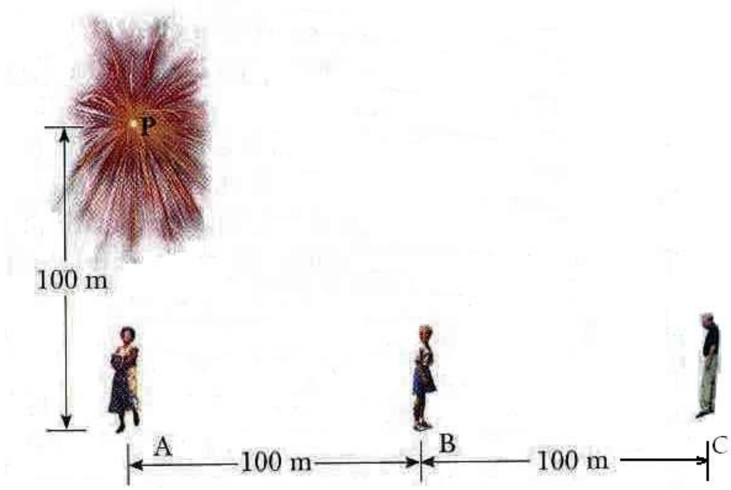
A. 0.5 m

B. 1.0 m

C. 2.0 m

D. None of the above

MC-9. (5 marks) A skyrocket explodes 100 m above the ground (Figure below). Three observers are spaced 100 m apart, with observer A standing directly under the point of the explosion.



What is the ratio of sound intensities I_A / I_C, heard by observers A and C ?

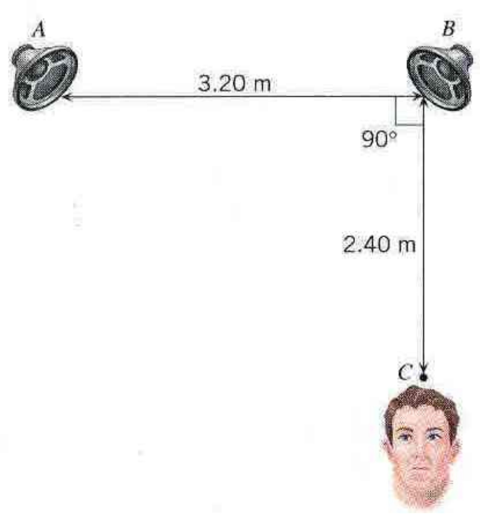
A. $I_A / I_C = 1/5$

B. $I_A / I_C = 1/4$

C. $I_A / I_C = 4$

D. $I_A / I_C = 5$

MC-10. (5 marks) Two in-phase loudspeakers, A and B, are separated by 3.20 m. A listener is stationed at point C, which is 2.40 m in front of speaker B. Assume that both speakers are playing tones with identical frequencies, and take the speed of sound equal to 343 m/s.



If the listener hears no sound as a result of destructive interference, what is the lowest possible frequency emitted by the loudspeakers?

A. 107 Hz
B. 214 Hz
C. 429 Hz
D. None of the above

MC-11. (3 marks) A single-slit diffraction image is formed on a distant screen. What effect does increasing the width of the slit have on the width of the central bright spot on the screen, assuming that the wavelength and the distance between the slit and the screen both remain constant ?

A. The central bright spot will become wider.
B. The central bright spot will become narrower.
C. The central bright spot will not change.
D. The width of the slit has no effect on the diffraction pattern.

MC-12. (3 marks) The blackbody spectrum from blackbody A peaks at a longer wavelength than that of blackbody B. Does this means that :

A. the temperature of A is greater than the temperature of B,
B. the temperature of A is equal to the temperature of B,
C. the temperature of A is lower than the temperature of B, or
D. the wavelength is not related to the temperature of the blackbody ?

MC-13. (4 marks) A beam of neutrons with a de Broglie wavelength of 0.250 nm diffracts from a crystal of table salt, which has an inter-ionic spacing of 0.282 nm. What is the angle of the second interference maximum?

A. 1.09º
B. 26.3º
C. 58.2º
D. 62.4º

[Problems begin on next page]

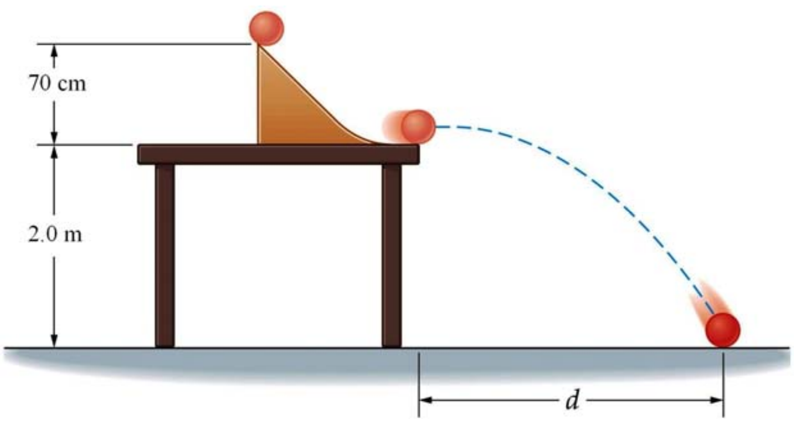
Problems (Total of 90 marks). Show all your calculations clearly.

P-1. (17 marks) Rotational Energy

A hollow sphere $\left(I_{CM} = \frac{2}{3} MR^2 \right)$ with a diameter of 12 cm is released from rest; it then rolls without slipping down a ramp, dropping through a vertical height of 70 cm. When it leaves the bottom of the ramp, which is 2.0 m above the floor, it is moving horizontally.

A. What is the speed *v* of the ball just as it leaves the ramp ? **[9 points]**

B. Through what horizontal distance *d* does the ball move before landing ? **[8 points]**



SOLUTION

A. $K_i + U_i = K_f + U_f$

$$mgh_i = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{3}mr^2\right)\left(\frac{v}{r}\right)^2 = \frac{5}{6}mv^2$$

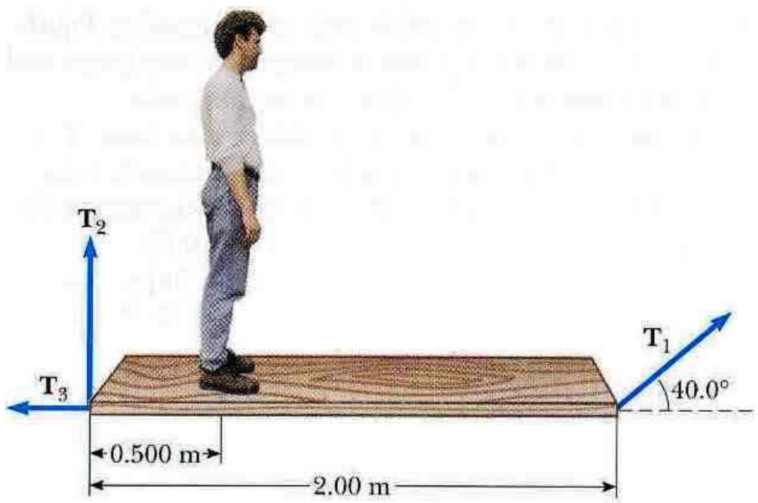
$$v = \sqrt{\frac{6}{5}gh} = 2.87 \text{ m/s}$$

B. $y = y_0 - \frac{1}{2}gt^2$ gives $t = \sqrt{\frac{2y_0}{g}}$, and

$$d = x = vt = v\sqrt{\frac{2y_0}{g}} = 1.83 \text{ m}$$

P-2. (16 marks) Static Equilibrium

A 30.0-kg uniform plank of length 2.0 m is supported by three ropes, as indicated below by the vectors $\boldsymbol{T}_1$, $\boldsymbol{T}_2$ and $\boldsymbol{T}_3$. What is the tension in each rope when a 700-N person is standing at 0.50 m from the left end ?



SOLUTION

$$\sum F_x : \qquad T_1 \cos 40 - T_3 = 0$$

$$\sum F_y : \qquad T_1 \sin 40 + T_2 - (m + M)g = 0$$

$$\sum \tau : \qquad 0.5mg + (1)Mg - T_1(2)\sin 40 = 0$$

From these equations, we find

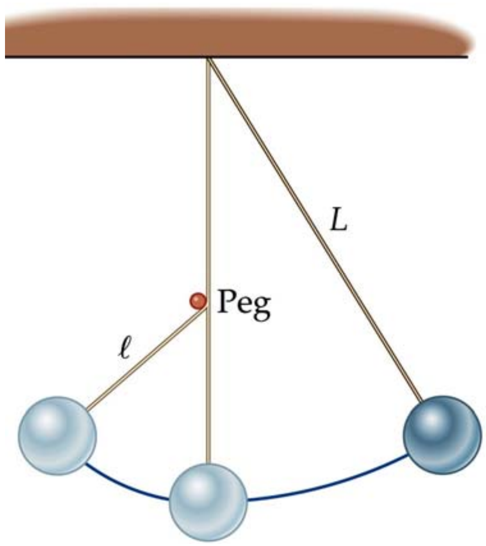
$T_1 = 501$ N, $T_2 = 672$ N, $T_3 = 384$ N

P-3. (10 marks) Simple Pendulum

The string of the pendulum displayed below is stopped by a peg when the bob swings to the left, but moves freely when the bob swings to the right.

A. Calculate the period of this pendulum in terms of L and l. **[8 points]**

B. Evaluate your result for $L = 1.0$ m and $l = 0.25$ m. **[2 points]**



SOLUTION

A. $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{\text{length}}{g}}$

Left half: $T_\ell = \frac{1}{2}2\pi\sqrt{\frac{\ell}{g}} = \pi\sqrt{\frac{\ell}{g}}$

Right half: $T_L = \frac{1}{2}2\pi\sqrt{\frac{L}{g}} = \pi\sqrt{\frac{L}{g}}$

Total period $T = T_\ell + T_L = \pi\left(\sqrt{\frac{\ell}{g}} + \sqrt{\frac{L}{g}}\right)$

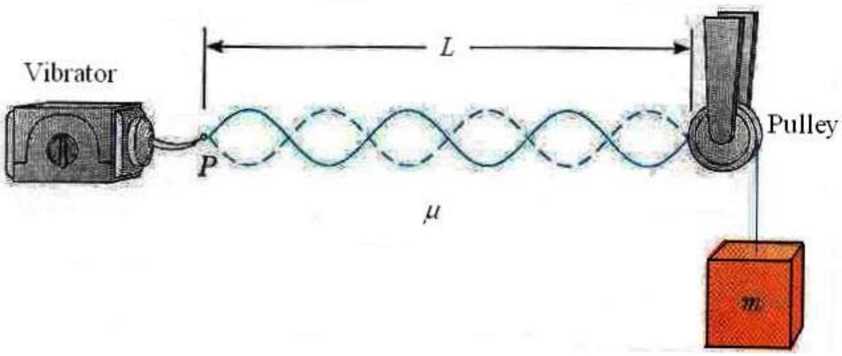
B. $T = 1.50$ s

P-4. (17 marks) Standing Waves

In the arrangement shown below, a mass $m = 5.0$ kg hang from a string around a light pulley. The length of the string between point *P* and the pulley is $L = 2.0$ m. When the vibrator is set to a frequency of 150 Hz, a standing waves with six loops is formed.

A. What must be the linear mass density of the string, in kg/m ? **[11 points]**

B. How many loops (if any) will result if m is increased to 45 kg ? **[6 points]**



SOLUTION

A. 6 loops (or half-waves) means $f_6 = 6f_1 = 150$ Hz, so that $f_1 = 25$ Hz

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{mg}{\mu}} \text{ and } f_1 = \frac{v}{2L} \text{ lead to } \mu = \frac{mg}{v^2} = \frac{mg}{(2f_1L)^2} = 4.91\times10^{-3} \text{ kg/m}$$

B. If m is multiplied by a factor 9, then v, and therefore f_1, are multiplied by a factor 3. In other words, the new f_1 is 75 Hz. Therefore, 150 Hz = 2 (75 Hz) is f_2, so that there are two loops.

P-5. (17 marks) Young's Two-Slit Experiment

In Young's experiment, a mixture of orange light (611 nm) and blue light (471 nm) shines on the double slit. The first-order ($m = 1$) bright blue fringes lie at the outer edges of a screen that is located 50 cm away from the slits. However, the first-order orange fringes fall off the screen. By how much and in which direction (toward or away from the slits) should the screen be moved, so that the first-order bright orange fringes just appear on the screen ? (It may be assumed that θ is small, so that $\sin\theta \approx \tan\theta$.)

SOLUTION

Since θ (angular width of the interference pattern) is proportional to λ, the orange light produces a wider pattern than the blue light. Thus the screen should be moved toward the slits in order that the first-order bright orange fringes just appear on the screen.

From $d\sin\theta = m\lambda$ and $y = L\tan\theta$, one finds, with $\sin\theta \approx \tan\theta$, that $\frac{y}{L} \approx \frac{m\lambda}{d}$. With $m = 1$, we obtain $L \approx \frac{yd}{\lambda}$. Since y and d are the same, we find $\frac{L_{\text{blue}}}{L_{\text{orange}}} = \frac{\lambda_{\text{orange}}}{\lambda_{\text{blue}}}$. The distance by which the screen should be moved is

$$L_{\text{blue}} - L_{\text{orange}} = L_{\text{blue}} - \frac{\lambda_{\text{orange}} L_{\text{blue}}}{\lambda_{\text{blue}}} = L_{\text{blue}}\left(1 - \frac{\lambda_{\text{orange}}}{\lambda_{\text{blue}}}\right) = (50)\left(1 - \frac{471}{611}\right) = 11.5 \text{ cm}$$

P-6. (13 marks) Photoelectric Effect

A metallic surface is illuminated with light of wavelength 300 nm. The work function for the metal is 2.46 eV. (Note: 1 eV = 1.60×10^{-19} J)

A. Find the maximum kinetic energy (in eV) of the ejected photoelectrons. **[9 points]**

B. Find the maximal wavelength necessary to eject photoelectrons. **[4 points]**

SOLUTION

A. $K_{max} = hf - W_0 = \frac{hc}{\lambda} - W_0 =$ 2.69×10^{-19} J ou 1.68 eV

B. $f_0 = \frac{W_0}{h} = \frac{c}{\lambda_0}$ so that $\lambda_0 = \frac{hc}{W_0} =$ 505 nm