UNIVERSITY OF MANITOBA

April 13, 2011 — FINAL EXAMINATION
(9:00 am – 12:00 pm) — PAGE NO.: 1 of 6 (+ formula sheet)

DEPARTMENT & COURSE NO.: PHYS 1070 — TIME: 3 hours

EXAMINATION: Physics 2: Waves and Modern Physics — EXAMINERS: G. Gwinner, P. Blunden

Equal marks for all 29 questions. No marks are subtracted for wrong answers.

Record all answers on the computer score sheet provided. **USE PENCIL ONLY!** Black pen will look good but may not be read reliably by the scoring machine. **Mark only <u>one</u> answer for each question!** Select the answer which is closest to yours.

A formula sheet is provided for your use; you may **not** use your own formula sheet. Calculators of any type are allowed, but not devices that store text or that can communicate with other such devices.

Be sure your name and student number are printed on the score sheet and the student number is correctly coded in the box at the top right-hand side of the sheet.

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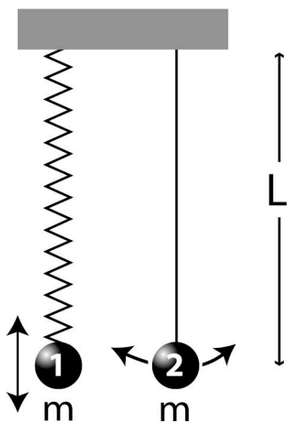
1. A chair of mass 15 kg is suspended by the ceiling by a spring. It oscillates vertically in simple harmonic motion with a period $T = 0.9$ s. When a person sits in the chair (not touching the ground), the oscillation period increases to 2.3 s. What is the mass of that person?

   (a) 53 kg (b) 72 kg (c) 83 kg (d) 98 kg (e) 108 kg

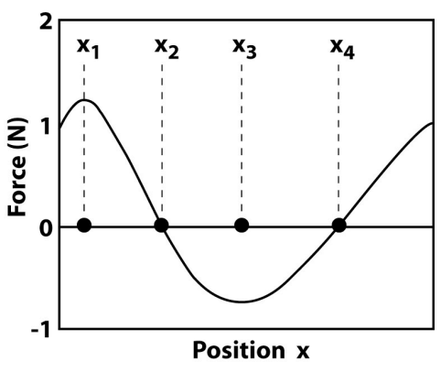
2. Consider two identical objects each weighing 1 N. Object 1 is suspended vertically from a spring (spring constant $k = 1.5$ N/m, equilibrium length L) and undergoes simple harmonic motion. Object 2 is at the end of a light cord of the same length L, oscillating as a simple pendulum and is found to oscillate at half the frequency of object 1. What is the length L?

   (a) 2.7 m (b) 26 m (c) 1.3 m (d) 4.0 m (e) 9.8 m



3. A particle constrained to move along the x-axis is subject to the force $F_x(x)$, plotted in the figure. Four points x_1 through x_4 are shown in the figure. Imagine the particle brought near to one of these and released. Near which points would you expect simple harmonic motion of the particle to take place?

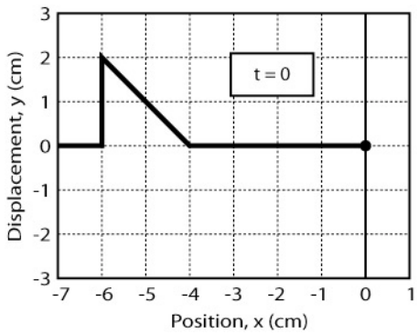
   (a) x_1 only (b) x_2 only (c) x_3 only (d) x_4 only
   (e) x_2 or x_4

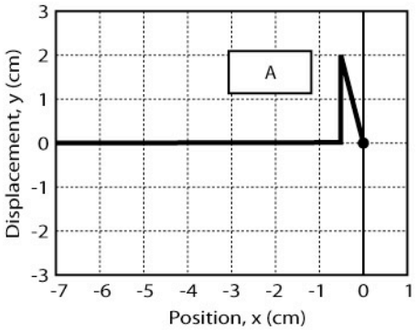


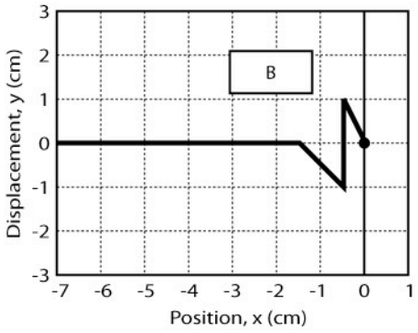
4. The fundamental frequency of a pipe that has one end closed is 256 Hz. When both ends of the same pipe are opened, the fundamental frequency is

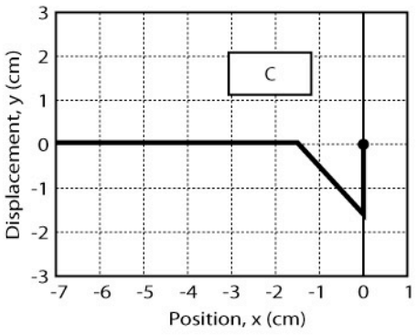
   (a) 64 Hz (b) 128 Hz (c) 256 Hz (d) 512 Hz (e) 1024 Hz

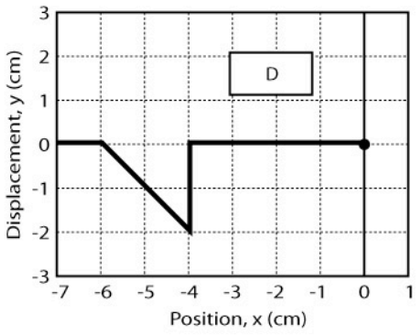
5. A "sawtooth" pulse travels along a string toward the string's fixed end at $x = 0$. The propagation speed of the pulse is 1.0 cm/s. Choose the figure below which most closely depicts the shape of the string at time $t = 5.5$ s.

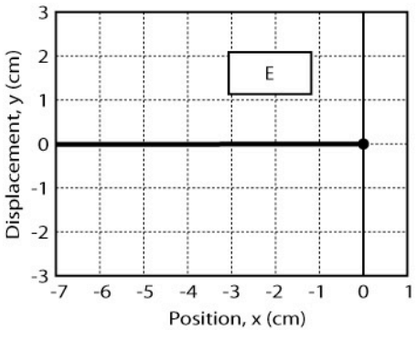




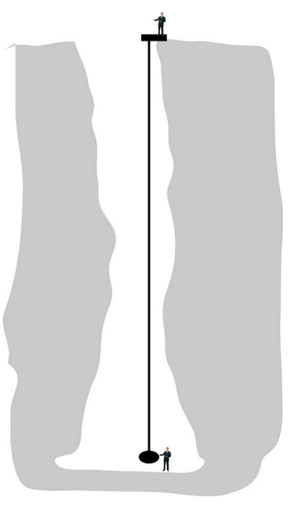








6. As indicated in the figure, one end of an 80.0 m long rope is tied to a fixed support at the top of a vertical mine shaft. The rope is under tension due to the weight of a box of mineral samples, of mass 20.0 kg, attached to the lower end. The mass of the rope is 2.00 kg. By tugging sideways on the rope, the person at the bottom of the mine shaft sends a transverse wave pulse to signal the person at the top. How long does it take this signal to reach its destination at the top of the mine shaft? (Assume that the tension in the rope is due to the box of samples only).

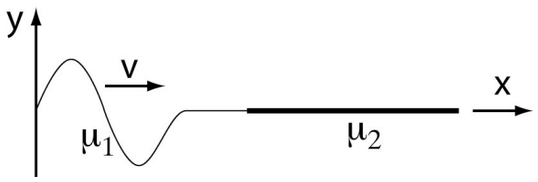


(a) 0.01 s (b) 0.37 s (c) 0.90 s (d) 1.1 s
(e) 2.8 s

7. Two sinusoidal waves travel in the same direction and have the same frequency. Their amplitudes are y_{1m} and y_{2m}. The smallest possible amplitude of the resultant wave is:

(a) $y_{1m} + y_{2m}$ and occurs if they are in phase
(b) $| y_{1m} - y_{2m} |$ and occurs if they are out of phase by π rad
(c) $| y_{1m} - y_{2m} |$ and occurs if they are out of phase by π/2 rad
(d) $y_{1m} + y_{2m}$ and occurs if they are out of phase by π rad
(e) $| y_{1m} - y_{2m} |$ and occurs if they are in phase

8. A travelling wave, $y = y_m \sin(2\pi x/\lambda - 2\pi ft)$, is sent along a horizontal string, as indicated in the diagram. The string consists of two sections with linear mass densities, μ_1 and μ_2, respectively, and $\mu_2 > \mu_1$. The tension in the string everywhere has the value τ. The speed of the wave in the lighter section of string is v, as shown. Which of the following statements correctly describes the wave when it has entered the heavier section of string, with density μ_2?



(a) The wave is moving faster, with speed $v_2 = (\mu_2 / \mu_1)v$
(b) The wave is moving slower, with speed $v_2 = (\mu_1 / \mu_2)v$
(c) The wavelength is longer, with value $\lambda_2 = \lambda\sqrt{\mu_2 / \mu_1}$
(d) The wavelength is shorter, with value $\lambda_2 = \lambda\sqrt{\mu_1 / \mu_2}$
(e) The frequency is lower, with value $f_2 = f\sqrt{\mu_1 / \mu_2}$

9. When a certain string is clamped at both ends, the lowest four resonant frequencies are 50, 100, 150, and 200 Hz. When the same string is also clamped at its midpoint, the lowest four resonant frequencies are:

(a) 50, 100, 150, and 200 Hz
(b) 50, 150, 250, and 300 Hz
(c) 100, 200, 300, and 400 Hz
(d) 25, 50, 75, and 100 Hz
(e) 100, 200, 400, and 800 Hz

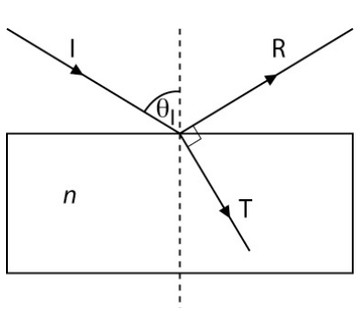
10. An observer initially stands at a distance d_1 from a sound source. She then walks to a new location 30 m further away from the source, and notices a drop in sound intensity by a factor of 2. What is the value of d_1?

(a) 52 m (b) 152 m (c) 6 m (d) 72 m (e) 30 m

11. A skydiver falling at a constant speed carries a buzzer which emits a sound of frequency 1800 Hz. Her friend standing directly below her on the ground measures the frequency of these sound waves to be 2150 Hz. What frequency does the skydiver measure for the sound waves reflected from the ground? Assume the speed of sound is 343 m/s.

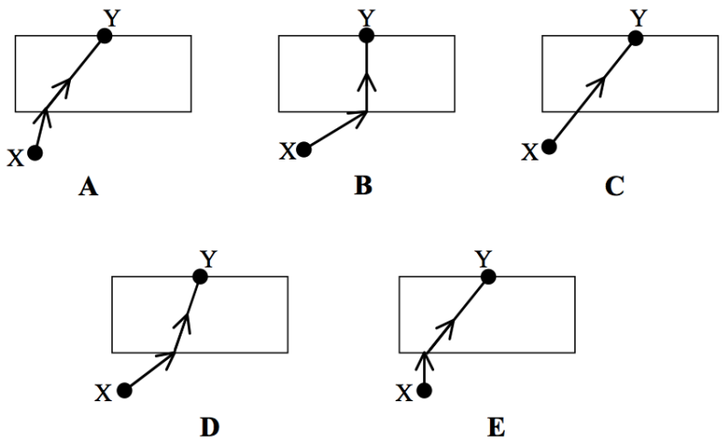
(a) 1800 Hz (b) 2150 Hz (c) 2500 Hz (d) 2435 Hz (e) 2570 Hz

12. A light ray (I) travelling through air ($n_{air} = 1$) is incident on a slab of material with refractive index n as shown in the diagram. Part of the light is reflected (R) and part of it is transmitted (T) at the interface. What is the value of n if the angle between the reflected and transmitted rays is 90°? (Hint: $\sin(90°\text{-}x) = \cos(x)$).



(a) $n = \tan(\theta_I)$ (b) $n = \sin(\theta_I)$ (c) $n = \cos(\theta_I)$
(d) $n = \cot(\theta_I)$ (e) $n = 1$

13. Which diagram below illustrates the path of a light ray as it travels from a given point X in air to another given point Y in glass?



14. A ray of light passes from air into water, striking the surface of the water with an angle of incidence of 45°. Which of the following four quantities change as the light enters the water: (1) wavelength; (2) frequency; (3) speed of propagation; (4) direction of propagation.

(a) 1 and 2 only (b) 2, 3, and 4 only (c) 1, 3, and 4 only (d) 3 and 4 only
(e) 1, 2, 3, and 4

15. Two one-dimensional traps have infinite potential energy at their walls. Trap A has width L and trap B has width $3L$. For which value of the quantum number n does a particle in trap B have the same energy as a particle in the ground state of trap A?

(a) $n = 1$ (b) $n = 2$ (c) $n = 3$ (d) $n = 4$ (e) $n = 5$

16. When a hydrogen atom makes the transition from the second excited state to the ground state (at –13.6 eV) the wavelength of the emitted photon is:

(a) 821 nm (b) 365 nm (c) 137 nm (d) 103 nm (e) 91 nm

17. In a photoelectric effect experiment at a frequency above cut off, the stopping potential is proportional to:

(a) the energy of the least energetic electron before it is ejected
(b) the energy of the least energetic electron after it is ejected
(c) the energy of the most energetic electron before it is ejected
(d) the energy of the most energetic electron after it is ejected
(e) the electron potential energy at the surface of the sample

18. The intensity of a light beam with a wavelength of 500 nm is 2000 W/m^2. The photon flux (in number/m^2 · s) is about:

(a) 5×10^{17} (b) 5×10^{19} (c) 5×10^{21} (d) 5×10^{23} (e) 5×10^{25}

19. Electromagnetic radiation with a wavelength of 5.7 pm is incident on stationary electrons. Radiation that has a wavelength of 6.268 pm is detected at a scattering angle of:

(a) 10° (b) 121° (c) 40° (d) 50° (e) 69°

20. Electromagnetic radiation with a wavelength of 3.5 pm is scattered from stationary electrons and photons that have been scattered through 50° are detected. An electron from which one of these photons was scattered receives an energy of:

(a) 0 (b) 69 keV (c) 119 keV (d) 144 keV (e) 811 keV

21. Identical particles, each with energy E, are incident on the following four potential energy barriers:
1. barrier height = $5E$, barrier width = $2L$
2. barrier height = $10E$, barrier width = L
3. barrier height = $17E$, barrier width = $L/2$
4. barrier height = $26E$, barrier width = $L/3$

Rank the barriers in terms of the probability that the particles tunnel through them, from least probability to greatest probability.

(a) 1, 2, 3, 4
(b) 4, 3, 2, 1
(c) 1 and 2 tied, then 3, then 4
(d) 2, then 2 and 3 tied, then 4
(e) 3, 2, 1, 4

22. Two stars that are close together are photographed through a telescope. The black and white film is equally sensitive to all colors. Which situation would result in the most clearly separated images of the stars? (λ_{blue}=475 nm, λ_{red}=650 nm)

(a) Small lens, red stars
(b) Small lens, blue stars
(c) Large lens, red stars
(d) Large lens, blue stars
(e) Large lens, one star red and the other blue

23. When 400-nm light is incident normally on a certain double-slit system the number of interference maxima within the central diffraction maximum is 5. When 800-nm light is incident on the same slit system the number is:

(a) 2 (b) 3 (c) 5 (e) 9 (e) 10

24. 600-nm light is incident on a defraction grating with a ruling separation of 1.7×10^{-6} m. The second order line occurs at a diffraction angle of:

(a) 0 (b) 10° (c) 21° (d) 42° (e) 45°

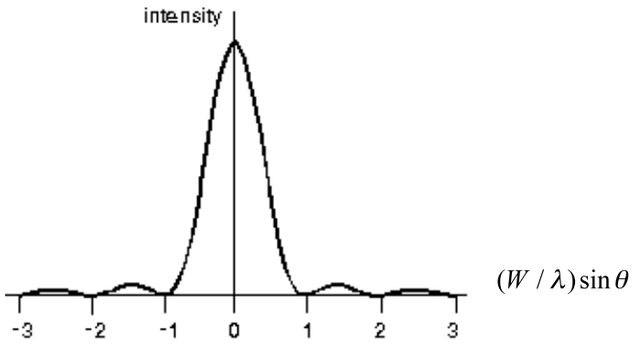
25. The largest x-ray wavelength that can be diffracted by crystal planes with a separation of 0.316 nm is:

(a) 0.158 nm (b) 0.316 nm (c) 0.474 nm (d) 0.632 nm (e) 1.26 nm

26. In a Young's double-slit experiment, light of wavelength 500 nm illuminates two slits which are separated by 1 mm. The separation between adjacent bright fringes on a screen 5 m from the slits is:

(a) 0.10 cm (b) 0.25 cm (c) 0.50 cm (d) 1.0 cm (e) none of the above

27. Light of wavelength λ is normally incident on some plane optical device. The intensity pattern shown is observed on a distant screen (θ is the angle measured to the normal of the device). The device could be:



(a) a single slit of width W
(b) a single slit of width $2W$
(c) two narrow slits with separation W
(d) two narrow slits with separation $2W$
(e) a diffraction grating with slit separation W

28. A soap film is illuminated by white light normal to its surface. The index of refraction of the film is 1.50. Wavelengths of 480 nm and 800 nm and no wavelengths between are to be intensified in the reflected beam. The thickness of the film is:

(a) 1.5×10^{-5} cm (b) 2.4×10^{-5} cm (c) 3.6×10^{-5} cm (d) 4.0×10^{-5} cm
(e) 6.0×10^{-5} cm

29. A glass ($n = 1.6$) lens is coated with a thin film ($n = 1.3$) to reduce reflection of certain incident light. If λ is the wavelength of the light in the film, the smallest film thickness is:

(a) less than λ/4 (b) λ/4 (c) λ/2 (d) λ (e) more than λ

THE END