UNIVERSITY OF MANITOBA

April 25, 2013 FINAL EXAMINATION
(6:00 pm – 9:00 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, J. Mammei

Equal marks for all 26 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 one 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 simple pendulum has a mass of 0.25 kg and length of 1.00 m. It is displaced by an angle of 0.26 rad from equilibrium and released. What is the maximum angular acceleration of the pendulum?

   (a) 2.5 rad/s^2 (b) 47 rad/s^2 (c) 3.1 rad/s^2
   (d) 147 rad/s^2 (e) 0.82 rad/s^2

2. An object undergoes simple harmonic motion according to the equation $x(t) = x_m \cos(\omega t + \varphi)$. The acceleration of the object at time $t = 0$ is a_0. The displacement of the particle at $t = 0$ is:

   (a) $-(a_0 \cos \varphi)/\omega^2$ (b) $-\omega^2 a_0 \cos \varphi$ (c) $\omega^2 a_0$ (d) $-a_0/\omega^2$ (e) $-\omega^2 a_0$

3. At time $t = 0$, the amplitude of an oscillator undergoing damped harmonic motion is 3.0 cm. At a time 2.0 seconds later the amplitude has decreased to 2.1 cm. What is the amplitude at time $t = 9.0$ s?

   (a) 0.30 cm (b) 0.40 cm (c) 0.50 cm (d) 0.60 cm (e) 0.70 cm

4. A transverse wave on a string is described by the equation $y = y_m \sin(kx - \omega t)$. Which of the following statements is correct about the motion of a mass element Δm in the string, at position x?

   (a) all mass elements execute simple harmonic motion along the x-axis at angular frequency ω.
   (b) the velocity of any given mass element is ω/k in the +x direction
   (c) the velocity of any given mass element is $d\omega/dk$ in the +x direction
   (d) the total energy of a mass element is constant in time
   (e) at time t, any two mass elements differ in phase by the amount $\Delta\varphi = k\,\Delta x$ where Δx is the distance between them.

5. Two traveling waves are described by $y_1 = y_m \sin(kx - \omega t)$ and $y_2 = y_m \sin(kx + \omega t)$ where $y_m =$ 5.00 cm, $k = \pi/2$ cm^{-1} and $\omega = 3\pi$ s^{-1}. What is the amplitude (in cm) of the resultant wave ($y_1 + y_2$) at location $x = 12.3$ cm?

   (a) 2.27 (b) 4.54 (c) 2.27 sin ωt (d) 4.54 sin ωt (e) 4.54 cos ωt

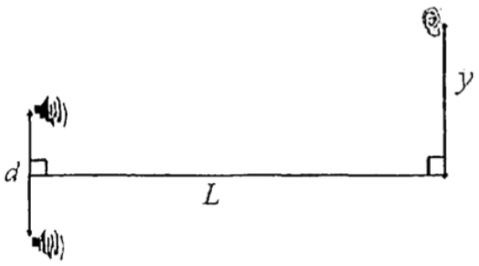
6. A 3.0 m long rope is stretched horizontally and fixed to two support posts. Under these conditions, the speed of transverse waves on the rope is 6.0 m/s. What is the lowest frequency at which vertical oscillations can be imposed on the rope in order to produce a node that is exactly in the center of the rope?

   (a) 1.0 Hz (b) 2.0 Hz (c) 3.0 Hz (d) 4.0 Hz (e) 6.0 Hz

7. A point source emits sound waves uniformly in all directions. If the sound level at a distance of 10 m from the source is 60 dB, what is the sound level at 40 m from the source?

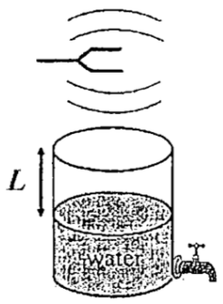
(a) 48 dB (b) 60 dB (c) 4 dB (d) 72 dB (e) 28 dB

8. Two speakers are driven in phase by the same oscillator and generate sound waves at a frequency of 600 Hz. The speakers are separated by a distance d = 0.8 m. At a perpendicular distance L = 10 m from the midpoint of the two speakers, the sound intensity is a maximum. At what location y as shown in the diagram will the first minimum in sound intensity occur? Use the fact that $L >> d$, but you CANNOT assume that $y << L$. The speed of sound is 340 m/s.



(a) 1.8 m (b) 3.5 m (c) 3.8 m (d) 7.0 m (e) 10 m

9. A tuning fork with a frequency of 440 Hz is held just above the top of an open tank containing water, as shown in the figure. The water level can be reduced by opening a tap at the bottom. The tank is partially filled initially. As the water is gradually drained out of the tank, the sound generated by the tuning fork gets much louder (i.e. it is in resonance with the tank) when the air column has a length of L = 0.6 m, and again when the air column has a length of L = 1.0 m, but not for any values of L in between. Use these observations to calculate the speed of sound in the air above the water surface.

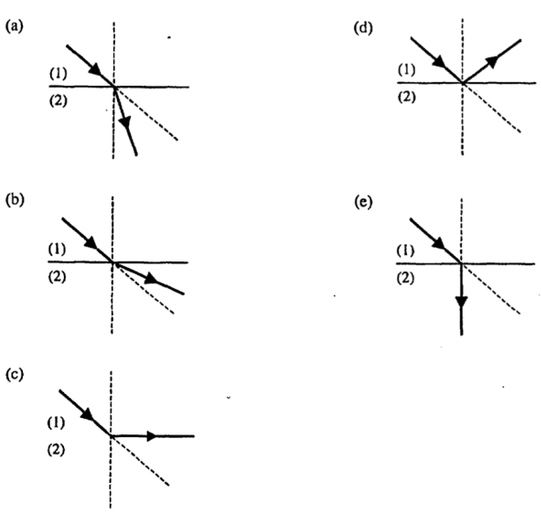


(a) 220 m/s (b) 264 m/s (c) 340 m/s (d) 352 m/s (e) 440 m/s

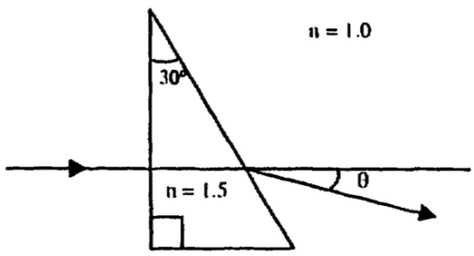
10. An ambulance siren is the source of sound emitted with a frequency of 1.60 kHz. The ambulance is driving toward the base of a large cliff at 95 km/h. What is the frequency of the reflected sound wave heard in the ambulance? (The speed of sound is 340 m/s).

(a) 3.18 kHz (b) 1.87 kHz (c) 1.72 kHz (d) 1.36 kHz (e) 1.17 kHz

11. Light travels from medium 1 to medium 2 with an incident angle of 45°. If the wavelength of the light in medium 2 is two thirds the wavelength in medium 1, then which of the following diagrams best represents the behaviour of the light ray?

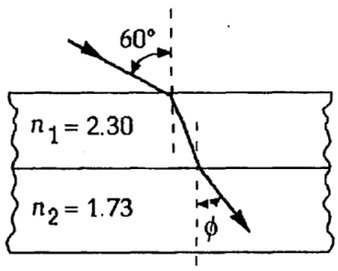


12. A light beam enters a glass prism (n = 1.50) at normal incidence as shown. The light emerges into air (n = 1.00) on the far side of the prism, deflected by an angle θ with respect to the direction of the incident light, as marked in the diagram. The value of θ is:



(a) 0° (b) 18.6° (c) 30°
(d) 48.6° (e) 60°

13. A ray of monochromatic light in air falls on the upper surface of two parallel-sided slabs of transparent material, as shown in the diagram. The angle of refraction φ in the lower slab is approximately



(a) 22° (b) 30° (c) 37°
(d) 53° (e) 60°

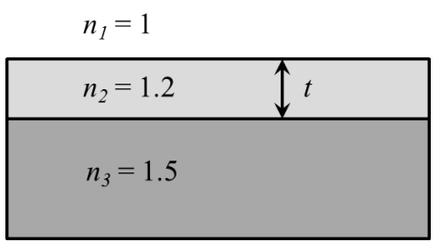
14. Light from a stationary spaceship is observed; then the spaceship moves directly away from the observer at high speed while still emitting light. As a result, the light seen by the observer has:

(a) a higher frequency and a longer wavelength than before
(b) a lower frequency and a shorter wavelength than before
(c) a higher frequency and a shorter wavelength than before
(d) a lower frequency and a longer wavelength than before
(e) the same frequency and wavelength as before

15. In a Young's double slit experiment there is a bright fringe on a distant screen where waves from the slits differ in phase by

(a) π/4 (b) π/2 (c) π (d) 3π/4 (e) 2π

16. Light is incident perpendicularly on a thin film as shown in the figure. What is the thickness of the film (t) that will give no reflection for light of wavelength 240 nm but maximum reflection for light of wavelength 420 nm?



(a) t = 350 nm (b) t = 380 nm
(c) t = 400 nm (d) t = 450 nm
(e) t = 600 nm

17. A slit of width a is illuminated by light of wavelength λ. A diffraction patterns is observed on a screen a distance D away. What is the distance, on the screen, between the first two diffraction minima on the same side of the central diffraction maximum? (Assume a small angle approximation to be valid.)

(a) $\lambda D/a$ (b) $\lambda D/2a$ (c) $2\lambda D/a$ (d) $a\lambda/D$ (e) $2a\lambda/D$

18. The radar system of a navy cruiser transmits and receives radio waves of wavelength 1.6 cm from a circular antenna with diameter 2.3 m. At a range of 6.2 km, what is the smallest distance that two speedboats can be from each other and still be resolved as two separate objects by the radar system?

(a) 27 m (b) 36 m (c) 53 m (d) 72 m (e) 106 m

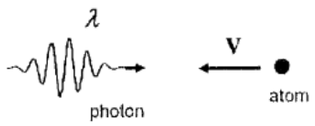
19. Light from a hydrogen discharge lamp is incident on a grating of 4000 lines/cm. Compute the angular separation, in the second order spectrum, between the α and δ lines of atomic hydrogen (wavelengths of 656 nm and 410 nm, respectively).

(a) 6.3° (b) 9.4° (c) 12.5° (d) 15° (e) 19°

20. An X-ray beam of wavelength λ_A undergoes first order reflection from a crystal when its angle of incidence to a family of crystal planes is 23° and an X-ray beam of wavelength 97 pm undergoes third order reflection when its angle of incidence to the same crystal planes is 60°. The wavelength λ_A is:

(a) 262 pm (b) 224 pm (c) 160 pm (d) 131 pm (e) 32 pm

21. By how much does a hydrogen atom (m = 1.67×10^{-27} kg or mc^2 = 939 MeV) slow down on absorbing a 121.6 nm photon with which it collides head on (as shown in the figure)?

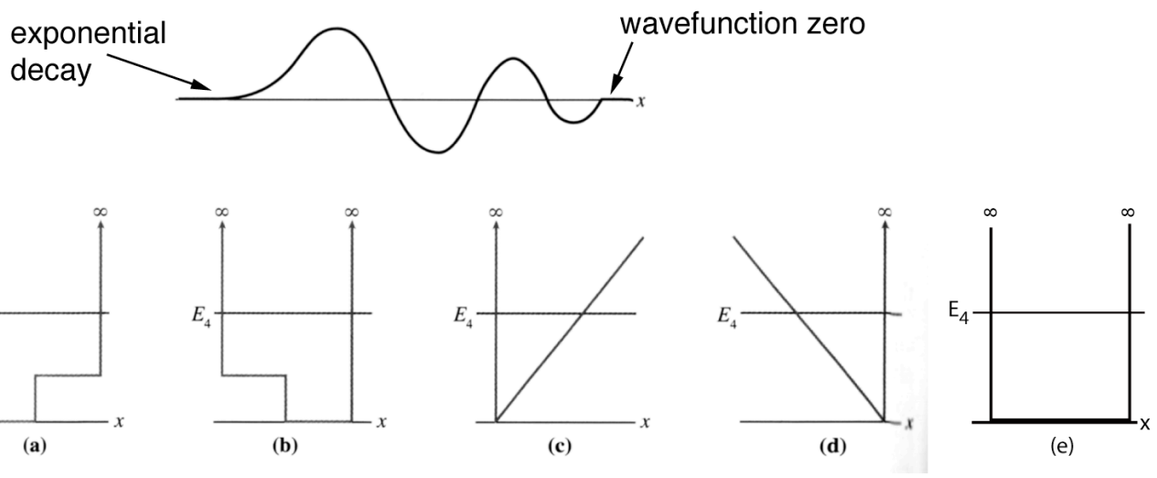


(a) 3.3 ms^{-1} (b) 3.3×10^{-1} ms^{-1} (c) 3.3×10^{-2} ms^{-1} (d) 1.1×10^{-8} ms^{-1} (e) 33 ms^{-1}

22. A photodetector converts incident light to electrical current by the photoelectric effect. Which material(s) could you use to construct the detector's light sensitive surface if you wish to detect visible radiation at 550 nm? (The material's work function is shown in parenthesis.)

(a) cesium (2.14 eV) (b) lithium (2.9 eV) (c) barium (2.7 eV)
(d) both cesium and lithium (e) none of these materials

23. For which potential well shown in the lower half of the picture is the n=4 wavefunction in the upper half appropriate?



24. $\psi(x)$ is the wave function for a particle moving along the x axis. The probability that the particle is in the interval from $x = a$ to $x = b$ is given by:

(a) $\psi(b) - \psi(a)$ (b) $|\psi(b)|^2 - |\psi(a)|^2$ (c) $|\psi(b) - \psi(a)|^2$
(d) $\int_a^b \psi(x)\,dx$ (e) $\int_a^b |\psi(x)|^2 dx$

25. The following wave function is a solution to the Schrödinger equation for an electron trapped in a one-dimensional infinite potential well, with x measured in nanometers:

$$\psi(x) = A \sin(4.2\,x).$$

The kinetic energy of the trapped electron is:

(a) 0.67 eV (b) 4.0 eV (c) 4.2 eV (d) 5.2 keV (e) 511 keV

26. The (three-dimensional) wave function for an electron in the ground state of the hydrogen atom is given by:

$$\psi(r) = \psi_0 e^{r/a_0}.$$

The constant ψ_0 has units:

(a) none; ψ_0 is dimensionless (b) m^{-1} (c) $m^{-1/2}$ (d) $m^{-3/2}$ (e) m^{-3}