April 16, 2014
(6:00 pm – 9:00 pm)

FINAL EXAMINATION

PAPER NO.: 129

PAGE NO.: 1 of 5 (+ 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 <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.

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

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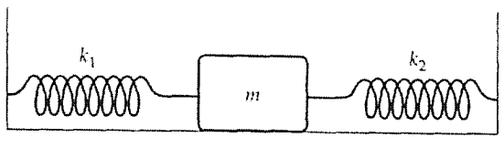
1. A particle moves back and forth along the x axis from $x = -x_m$ to $x = +x_m$, in simple harmonic motion with period T. At time $t = 0$, the particle is located at $x = -x_m$. When $t = 0.75$ T, the particle is:

   (a) at $x = 0$ and is traveling toward $x = +x_m$
   (b) at $x = 0$ and is traveling toward $x = -x_m$
   (c) at $x = +x_m$ and is at rest
   (d) between $x = 0$ and $x = +x_m$ and is traveling toward $x = -x_m$
   (e) between $x = 0$ and $x = -x_m$ and is traveling toward $x = -x_m$

2. The motion of a particle connected to a spring is described by $x = 10 \sin(\pi t)$, with x in metres and t in seconds. At which of the following times is its potential energy equal to its kinetic energy?

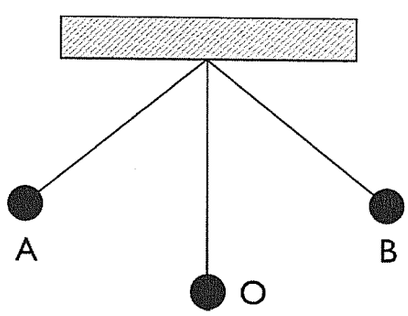
   (a) 0 s (b) 0.25 s (c) 0.50 s (d) 0.79 s (e) 1.0 s

3. The mass in the figure slides on a frictionless surface. If $m = 2.0$ kg, $k_1 = 800$ N/m and $k_2 = 500$ N/m, the frequency of oscillation is approximately



   (a) 6 Hz (b) 2 Hz (c) 4 Hz (d) 8 Hz (e) 10 Hz

4. An object of mass m is attached to a string of length L. When it is released from point A, the object oscillates between points A and B. Which statement about the pendulum in the gravitational field of the earth is correct?



   (a) The potential energy of the system is greatest at A and B
   (b) The kinetic energy of the mass m is greatest at point O
   (c) The greatest acceleration (in magnitude) occurs at A and B
   (d) All of the above
   (e) Only (a) and (b) above are correct

5. A sinusoidal wave $y = y_m sin(kx - \omega t)$ travels along a uniform horizontal string. If u_{max} denotes the maximum transverse particle speed and v is the wave speed, the ratio u_{max}/v is equal to:

(a) ky_m (b) ω/k (c) $2\pi ky_m$ (d) $\omega T/(k\lambda)$ (e) $\omega T/(ky_m)$

6. A tube is open at one end and closed at the other by a movable piston. A 384 Hz tuning fork is held at the open end. Resonance is heard when the piston is a distance L from the open end and, again, when it is at L+45.5 cm from the open end. From these data, the speed of sound is measured to be:

(a) 340 m/s (b) 343 m/s (c) 346 m/s (d) 349 m/s (e) 352 m/s

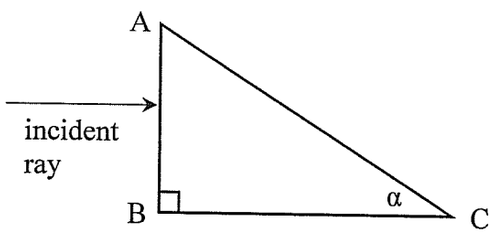
7. Two identical isotropic point sources emit sound waves in phase and are mounted on a vertical pole at heights of 0.30 m and 0.70 m from the floor. A microphone detector on the floor is initially situated at the pole and then slowly moved away (along the floor). The microphone detects a minimum in sound intensity when it reaches a distance of 0.53 m from the pole. Assuming the speed of sound in air to be 340 m/s, the frequency of the sound waves is:

(a) 318 Hz (b) 632 Hz (c) 953 Hz (d) 1270 Hz (e) 1588 Hz

8. A student holds a tuning fork oscillating at 256 Hz and walks away from a nearby wall at a constant speed. How fast must he walk to hear a beat frequency of 5.00 Hz between the sound of the tuning fork and its echo? (Assume the speed of sound to be 340 m/s.)

(a) 3.35 m/s (b) 4.45 m/s (c) 5.23 m/s (d) 6.70 m/s (e) 6.83 m/s

9. Light is incident normal to the face AB of a glass prism with refractive index n = 1.35, as shown in the figure. If the prism is immersed in air with refractive index 1.00, what is the largest value of the prism angle α, marked in the diagram, for which no light will emerge from the face AC?



(a) 42° (b) 48° (c) 49° (d) 52° (e) 60°

10. A stationary police officer holds a $f_0 = 2.00$ GHz radar unit and directs a signal towards a speeding car. The car is moving away from the police officer at a speed 100 km/hr. What frequency shift $\Delta f = f - f_0$ does the radar unit detect in the reflected signal from the speeding car?

(a) -93 Hz (b) -185 Hz (c) -370 Hz (d) -667 Hz (e) -1.33 kHz

11. A ray of light in water (index n_1) is incident on its surface (with air) at the critical angle for total internal reflection. A layer of oil (index n_2) is then introduced and floats on the surface of the water. The angle between the light ray in the oil and the normal is then:

(a) arcsin(1.00) (b) arcsin($1/n_1$) (c) arcsin($1/n_2$)
(d) arcsin(n_1/n_2) (e) arcsin(n_2/n_1)

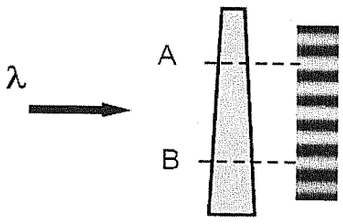
12. A spectral line of a certain star is observed to be "red shifted" from a wavelength of 500 nm to a wavelength of 1500 nm. Interpreting this as a Doppler effect, the speed of recession of this star is:

(a) 0.33 c (b) 0.50 c (c) 0.71 c (d) 0.8 c (e) c

13. A soap film (n=1.33) of uniform thickness covers a glass plate (n=1.50). Light of wavelength 600 nm is normally incident (from air) onto the soap film and is strongly reflected. Which of the following thicknesses of the film gives the strongest reflection?

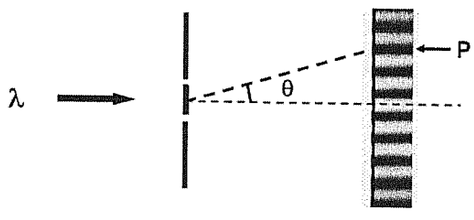
(a) 113 nm (b) 226 nm (c) 300 nm (d) 150 nm (e) 600 nm

14. Light of wavelength λ in air is incident on a thin film of refractive index $n = 1.5$ whose thickness varies with height. The interference pattern observed from the left hand side of the film is shown in the diagram. By what amount does the film thickness change between points A and B?



(a) 1.33 λ (b) 2 λ (c) 2.66 λ (d) 3 λ (e) 4 λ

15. Light of wavelength λ is incident on a double-slit apparatus, with slit separation d, as shown in the figure. What is the path difference between rays from the top and the bottom slits to point P at the center of the dark band indicated in the figure?



(a) d (b) λ (c) 2.5 d (d) 2.5 λ (e) 5 λ

16. 601 nm light is incident on a diffraction grating and produces a line at $\theta = 9.1°$. In the same order, a line produced by 600 nm light can be just resolved from a line produced by 602 nm light. What is the width of the grating?

(a) 0.60 μm (b) 2.3 μm (c) 100 μm (d) 1.1 mm (e) 5.6 mm

17. Light of wavelength 360 nm is incident on a diffraction grating. If the third order line is visible at $\theta = 34.7°$, what is the highest order visible for this wavelength?

(a) 3 (b) 4 (c) 5 (d) 6 (e) 7

18. In a photon-detecting device based on the photoelectric effect, electrons emitted from a metal surface with work function $\phi = 2.0$ eV are accelerated toward a positively charged collector plate through a potential difference $V_a = 25$ V. When light of wavelength $\lambda = 413$ nm is incident on the photoemission surface, what is the maximum kinetic energy of the electrons striking the collector plate?

(a) 3 eV (b) 5 eV (c) 25 eV (d) 26 eV (e) 28 eV

19. In a photoelectric effect experiment, a sample is irradiated with light at a frequency greater than the cutoff frequency. The number of electrons ejected from the sample is proportional to:

(a) their kinetic energy
(b) their potential energy
(c) the work function of the sample
(d) the frequency of the incident light
(e) the number of photons that hit the sample

20. In Compton scattering from stationary electrons, the largest change in wavelength that can occur is:

(a) 2.43×10^{-12} m (b) 2.43×10^{-9} m (c) 4.86×10^{-9} m (d) 4.86×10^{-12} m
(e) depends on the frequency of the light

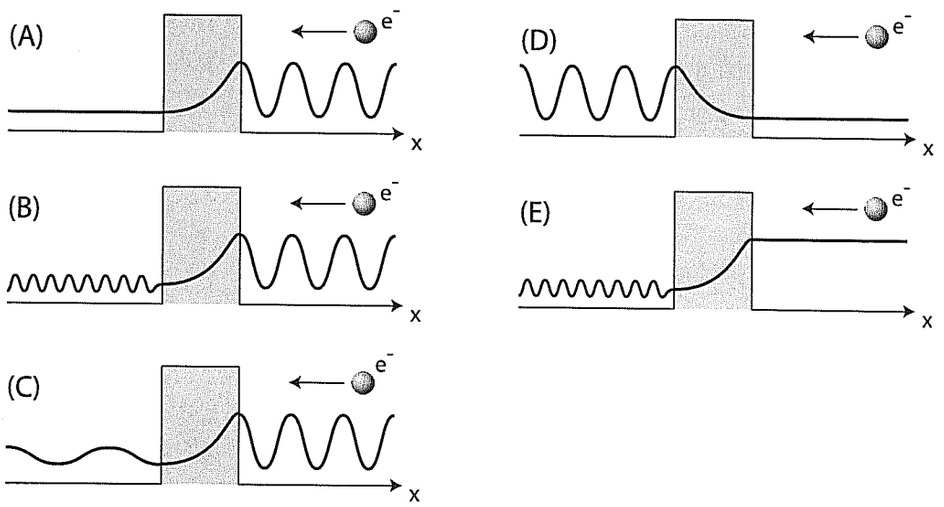
21. The uncertainty in the position of an electron is 5×10^{-10} m. Which of the following possible values of the uncertainty in its momentum are consistent with quantum mechanics?

(a) 5.0×10^{-24} kg m/s (b) 3.0×10^{-24} kg m/s (c) 4.0×10^{-24} kg m/s
(d) all of the above (e) none of the above

22. A free particle of mass m travelling in one dimension along the x-axis is described by the wave function $\psi(x,t) = \psi_0 e^{i(kx-\omega t)}$. What are the SI units of the constant ψ_0?

(a) $m^{-1/2}$ (b) m (c) m^{-2} (d) s^{-1} (e) ψ_0 is dimensionless

23. A free electron (energy E) coming from the right hits a potential barrier of height U_b, and $U_b > E$. The electron is either reflected back to the right or tunnels through the barrier to the left. Which one of the following plots showing the absolute square of the wave function $|\psi|^2$ describes this situation correctly?



24. An electron is trapped in a one-dimensional infinite potential well. Consider transitions between the following pairs of states:

(1) n = 3 → n = 1

(2) n = 3 → n = 2

(3) n = 4 → n = 3

Order these transitions by the amount of energy released, from smallest to largest.

(a) 1, 2, 3 (b) 3, 2, 1 (c) 2, 3, 1 (d) 1, 3, 2 (e) 3, 1, 2

25. An electron is trapped in a one-dimensional infinite potential well with $0 < x < 2$ nm. It is in the state $n = 5$. What is the probability of finding the electron in a small region of width $\Delta x = 2$ pm around the position $x = 0.1$ nm? The wave functions for the one-dimensional infinite well are given by

$$\psi_n = \sqrt{\frac{2}{L}} sin\left(\frac{n\pi}{L}x\right)$$

(Hint: You can consider the wave function to be constant across Δx.)

(a) 5×10^{-2} (b) 1×10^{-2} (c) 1×10^{-3} (d) 5×10^{-4} (e) 5×10^{-5}

26. The Bohr model can be applied to an ion consisting of one electron bound to a nucleus of charge Ze. If the radiation emitted in the $n = 5$ to $n = 4$ electron transition has a wavelength of 1013 nm, then what is the ground state energy of this ion?

(a) -1.22 eV (b) -10.2 eV (c) -13.6 eV (d) -27.2 eV (e) -54.4 eV

THE END