UNIVERSITY OF MANITOBA

April 17, 2012 — FINAL EXAMINATION
(9:00 am – 12:00 NOON) — 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, P. Blunden

Equal marks for all 27 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. The spring constant for a spring-mass system undergoing simple harmonic motion is doubled. If the total energy remains unchanged, what will happen to the amplitude of the oscillation? It will be

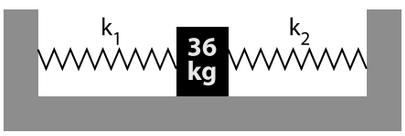
   (a) unchanged (b) multiplied by 2 (c) multiplied by 1/2

   (d) multiplied by $1/\sqrt{2}$ (e) multiplied by $\sqrt{2}$

2. A spring is hanging from the ceiling with a massive object attached to it. The object is pulled downward, causing it to oscillate vertically with simple harmonic motion. Which of the following will increase the frequency of oscillation?

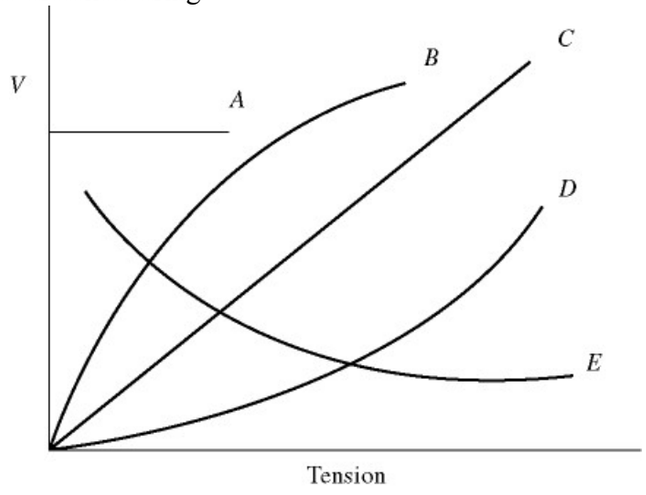
   (a) Adding a second, identical spring with one end attached to the object and the other to the ceiling
   (b) Inserting a second, identical spring between the object and the original spring
   (c) Increasing the mass of the object
   (d) Take the system to the moon, where the gravitational acceleration is smaller
   (e) All of the above

3. A 36-kg block is placed on a horizontal frictionless surface and then connected to walls by two springs with spring constants $k_1 = 3$ N/m and $k_2 = 4$ N/m, as shown in the figure. What is the period of oscillation for the block if it is displaced to one side?



   (a) 11 s (b) 14 s (c) 17 s (d) 20 s (e) 32 s

4. In the figure, which of the curves best represents the variation of wave speed as a function of tension for transverse waves on a stretched string?



   (a) A (b) B (c) C (d) D (e) E

5. A transverse wave is travelling on a string stretched along the horizontal x-axis. The equation for the vertical displacement y of the string is given by $y = 0.0020 \cos[\pi(15x - 52t)]$, where all quantities are in SI units. The maximum speed of an element of the string is closest to

(a) 0.33 m/s (b) 0.43 m/s (c) 0.53 m/s (d) 0.64 m/s (e) 0.74 m/s

6. Two violinists are trying to tune their instruments in an orchestra. One is producing the desired frequency of 440.0 Hz. The other is producing a frequency of 448.4 Hz. By what percentage should the out-of-tune musician change the tension in his string to bring his instrument into tune at 440.0 Hz?

(a) +1.9% (b) −1.9% (c) +3.7% (d) –3.7% (e) +8.4%

7. An air column, open at one end and closed at the other, is being designed so that its second lowest resonant frequency is 440 Hz. What should be the length of the column if the speed of sound in air is 340 m/s?

(a) 0.386 m (b) 0.772 m (c) 1.16 m (d) 0.193 m (e) 0.580 m

8. A howler monkey is the loudest land animal and, under some circumstances, can be heard up to a distance of 5.0 km. Assume the acoustic output of a howler to be uniform in all directions, and that the threshold of hearing I_0 is 1.0×10^{-12} W/m^2. The acoustic power emitted by the howler is closest to

(a) 11 mW (b) 0.11 mW (c) 1.1 mW (d) 3.2 mW (e) 0.31 mW

9. At a distance of 2.00 m from a point source of sound, the sound level is 80.0 dB. What will be the sound level at a distance of 4.00 m from this source?

(a) 77.0 dB (b) 74.0 dB (c) 60.0 dB (d) 40.0 dB (e) 20.0 dB

10. You are driving along a highway at 35.0 m/s when you hear the siren of a police car approaching you from behind. You perceive the frequency as 1370 Hz. You are relieved that he is in pursuit of a different car when he continues past you, but you now perceive the frequency as 1330 Hz. What is the speed of the police car? The speed of sound in air is 340 m/s.

(a) 38.4 m/s (b) 30.0 m/s (c) 39.2 m/s (d) 40.0 m/s (e) 41.7 m/s

11. When light goes from one material into another material having a higher index of refraction

(a) its speed, wavelength, and frequency all decrease
(b) its speed decreases but its wavelength and frequency both increase
(c) its speed and wavelength decrease, but its frequency stays the same
(d) its speed decreases but its frequency and wavelength stay the same
(e) its speed increases, its wavelength decreases, and its frequency stays the same

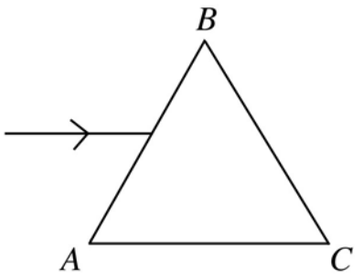
12. An oil layer that is 5.0 cm thick is spread smoothly and evenly over the surface of water on a windless day. What is the angle of refraction in the water for a ray of light that has an angle of incidence of 45° as it enters the oil from the air above? (The index of refraction for the oil is 1.15, and for water it is 1.33.)

(a) 27° (b) 39° (c) 36° (d) 32° (e) 52°

13. A ray of light consisting of blue light (wavelength 480 nm) and red light (wavelength 670 nm) is incident on a thick piece of glass at 80° relative to the surface normal. What is the angular separation between the refracted red and refracted blue beams while they are in the glass? (The respective indices of refraction for the blue light and the red light are 1.4636 and 1.4561.)

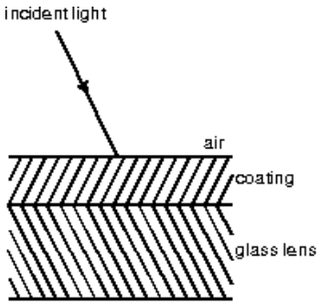
(a) 0.33° (b) 0.36° (c) 0.46° (d) 0.54° (e) 0.27°

14. Light in air is initially travelling parallel to the face *AC* of an equilateral triangular prism, as shown in the figure. The prism is made of glass with an index of refraction of 1.52. If the light does not strike the face *AC*, what is the angle between the ray as it leaves the prism at face *BC* and the normal in air at that face?



(a) 83° (b) 19° (c) 59° (d) 27° (e) 55°

15. A lens with a refractive index of 1.5 is coated with a material of refractive index 1.2 in order to minimize reflection. If the wavelength of the incident light in air is 600 nm, what is the thinnest possible such coating?



(a) 300 nm (b) 0.250 nm (c) 180 nm
(d) 125 nm (e) 150 nm

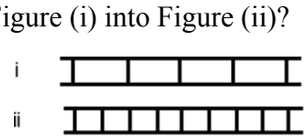
16. A double slit illuminated with light of wavelength 588 nm forms a diffraction pattern on a screen 11.0 cm away. The slit separation is 2464 nm. What is the distance between the third and fourth bright fringes away from the central fringe?

(a) 23.9 cm (b) 5.96 cm (c) 5.59 cm (d) 2.63 cm (e) 5.25 cm

17. Figure (i) shows a double-slit pattern obtained using monochromatic light. Consider the following five possible changes in conditions:

1. increase the wavelength
2. decrease the wavelength
3. increase the width of each slit
4. increase the separation between the slits
5. decrease the separation between the slits

Which of the above would change Figure (i) into Figure (ii)?



(a) 3 only (b) 5 only (c) 1 and 3 only
(d) 1 and 5 only (e) 2 and 4 only

18. A diffraction-limited laser of length *L* and aperture diameter *d* generates light of wavelength λ. If the beam is directed at the surface of the Moon a distance *D* away, the radius of the illuminated area on the moon is approximately:

(a) dD/L (b) dD/λ (c) $D\lambda/L$ (d) $D\lambda/d$ (e) $L\lambda/d$

19. Two slits of width a and separation d are illuminated by a beam of light of wavelength λ. The separation of the interference fringes on a screen a distance D away is:

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

20. Two slits in an opaque barrier each have a width of 0.020 mm and are separated by 0.050 mm. When coherent monochromatic light passes through the slits the number of interference maxima within the central diffraction maximum:

(a) is 1 (b) is 2 (c) is 4 (d) is 5
e) cannot be determined unless the wavelength is given

21. Light of wavelength 687 nm is incident on a single slit 0.75 mm wide. At what distance from the slit should a screen be placed if the second dark fringe in the diffraction pattern is to be 1.7 mm from the center of the diffraction pattern?

(a) 0.39 m (b) 0.47 m (c) 0.93 m (d) 1.1 m (e) 1.9 m

22. A metallic sheet has a large number of slits, 5.0 mm wide and 20 cm apart, and is used as a diffraction grating for microwaves. A wide parallel beam of microwaves is incident normally on the sheet. If the microwave wavelength is 6.0 cm, what is the largest angle away from the central maximum at which an intensity maximum occurs.

(a) 64° (b) 69° (c) 74° (d) 79° (e) 84°

23. Monochromatic light strikes a metal surface and electrons are ejected from the metal. If the intensity of the light is increased, what will happen to the ejection rate and maximum energy of the electrons?

(a) greater ejection rate; same maximum energy
(b) same ejection rate; greater maximum energy
(c) greater ejection rate; greater maximum energy
(d) same ejection rate; same maximum energy
(e) cannot be determined without knowing the work function of the metal

24. A metal having a work function of 2.4 eV is illuminated with monochromatic light of wavelength 310 nm. What is the maximum kinetic energy of the photoelectrons produced by this light?

(a) 1.6 eV (b) 2.4 eV (c) 2.9 eV (d) 3.4 eV (e) 4.0 eV

25. Separate Compton effect experiments are carried out using visible light and x rays. The scattered radiation is observed at the same scattering angle. For these experiments:

(a) the x rays have the greater shift in wavelength and the greater change in photon energy
(b) the two radiations have the same shift in wavelength and the x rays have the greater change in photon energy
(c) the two radiations have the same shift in wavelength and the visible light has the greater change in photon energy
(d) the two radiatons have the same shift in wavelength and the same change in photon energy
(e) the visible light has the greater shift in wavelength and the greater shift in photon energy

26. An electron of kinetic energy 80 eV encounters a potential barrier 100 eV high and 0.20 nm thick. What is the probability the electron will tunnel through the barrier?

(a) 0.011% (b) 1.1% (c) 0.11%
(d) 1.1×10^{-4} % (e) 7.7×10^{-10} %

27. Identical particles are trapped in one-dimensional wells with infinite potential energy at the walls. The widths L of the traps and the quantum numbers n of the particles are

1. $L = 2L_0$, $n = 2$
2. $L = 2L_0$, $n = 1$
3. $L = 3L_0$, $n = 3$
4. $L = 4L_0$, $n = 2$

Rank them according to the energies of the particles, least to greatest.

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