# UNIVERSITY OF SASKATCHEWAN

## Department of Physics and Engineering Physics

## Physics 117.3
## FINAL EXAMINATION

April 24, 2018 Time: 180 minutes

NAME: SOLUTIONS MASTER STUDENT NO.: ____________

(Last) **Please Print** (Given)

LECTURE SECTION (please check):

❑ 01 Adam Zulkoskey

❑ 02 Brian Zulkoskey

**INSTRUCTIONS:**

1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card and an OMR sheet. The test paper consists of 12 pages, including this cover page. **It is the responsibility of the student to check that the test paper is complete**.
3. Only a basic scientific calculator (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, are **not** allowed.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your name on the exam booklet and scratch card.
5. Enter your name and encode your NSID on the OMR sheet, **using a pencil**.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

| QUESTION # | MAX. MARKS | MARKS |
|---|---|---|
| A1-20 | 20 | |
| B21-24 | 8 | |
| B25-28 | 8 | |
| B29-32 | 8 | |
| B33-36 | 8 | |
| B37-40 | 8 | |
| B41-44 | 8 | |
| MARK | out of 60: | |

**PART A**

**FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET, USING A PENCIL. USE THE EXAM BOOKLET FOR YOUR ROUGH WORK.**

A1. Consider a large rectangular block of wood that has a weight of $1.8 \times 10^4$ N and dimensions of 1 m $\times$ 2 m $\times$ 3 m. Which one of the following statements is correct concerning the pressure(s) that the block of wood can exert on a flat horizontal floor?

A

(A) The pressure exerted by the block can be 9000 Pa, 6000 Pa, or 3000 Pa, depending on its orientation.
(B) The pressure exerted by the block can only be 9000 Pa.
(C) The pressure exerted by the block can only be 6000 Pa.
(D) The pressure exerted by the block can only be 3000 Pa.
(E) The pressure exerted by the block can be 9000 Pa or 6000 Pa, but not 3000 Pa.

$P = \frac{F}{A} = \frac{18000\text{N}}{2\text{m}^2}; \frac{18000\text{N}}{3\text{m}^2}; \frac{18000\text{N}}{6\text{m}^2}$

A2. An ice cube is floating at rest in a glass of water. What happens to the level of the water in the glass as the ice cube melts?

A

(A) Nothing, the water level does not change.
(B) The water level rises as the ice cube melts.
(C) The water level falls as the ice cube melts.
(D) The water level could either rise or fall, depending on the initial weight of the ice cube.
(E) The water level could either rise or fall, depending on the initial volume of the ice cube above the water level.

At any instant, the ice cube displaces a volume of water with the same mass as the ice cube. That is, the amount of liquid water that the ice cube represents will exactly "fill" the volume of water that has been displaced.

A3. Which one of the following statements best describes the situation in a hydraulic lift.

C

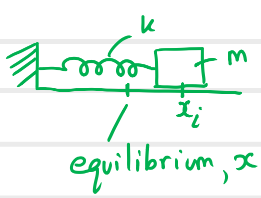
(A) A small pressure change in a small cylinder produces a large pressure change in a large cylinder.
(B) A small pressure change in a large cylinder produces a large pressure change in a small cylinder.
(C) A small force applied to a small piston produces a large force on a large piston.
(D) A small force applied to a large piston produces a large force on a small piston.
(E) A small displacement of a small piston produces a large displacement of a large piston.

Pascal's Principle: $\Delta P_s = \Delta P_\ell \Rightarrow F_s/A_s = F_\ell/A_\ell \Rightarrow F_\ell = F_s\left(\frac{A_\ell}{A_s}\right)$

A4. A horizontal mass-spring system obeys Hooke's Law. The mass sits on a horizontal, frictionless surface and is placed at an initial position of 4.0 cm relative to the equilibrium position before being released. The force constant of the spring is 250 N/m. Calculate the total energy of the mass-spring system.

E

(A) 1000 J (B) 5.0 J (C) 2000 J (D) 4000 J (E) 0.20 J

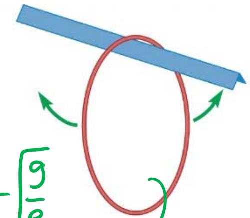



$E = PE_{max} = \frac{1}{2}kx_i^2$

$E = \frac{1}{2}\left(250\frac{\text{N}}{\text{m}}\right)(0.040\text{m})^2 =$

A5. A thin circular hoop is suspended from a knife edge as shown in the figure. Its rotational inertia about the rotation axis (along the knife edge) is $I = 2MR^2$. You want to compare its frequency of oscillation to that of a simple pendulum that has its mass suspended at a distance equal to the radius of the hoop. Let $f$ be the frequency of oscillation of the simple pendulum. The frequency of oscillation of the hoop is

B



$f_{simple} = \frac{1}{2\pi}\sqrt{\frac{g}{R}}$

(A) $\frac{f}{2}$ (B) $\frac{f}{\sqrt{2}}$ (C) $f$ (D) $\sqrt{2}f$ (E) $2f$

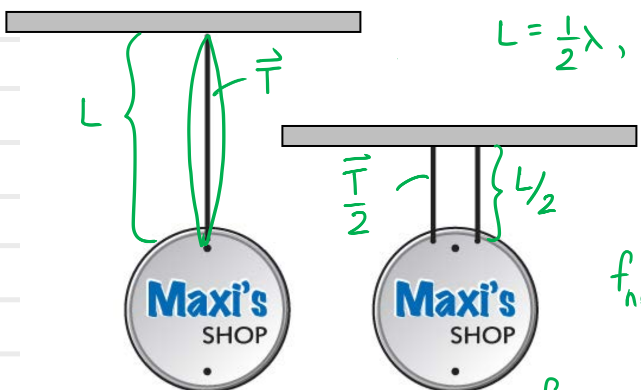
Physical Pendulum: $T_p = 2\pi\sqrt{\frac{I}{mgL}} = 2\pi\sqrt{\frac{2MR^2}{MgR}} = 2\pi\sqrt{2}\sqrt{\frac{R}{g}} \Rightarrow f_p = \frac{1}{2\pi\sqrt{2}}\sqrt{\frac{g}{R}}$ ; $f_p = \frac{f_{simple}}{\sqrt{2}}$

A6. A sign is hanging from a single metal wire, as shown in the left part of the accompanying figure. The shop owner notices that the wire vibrates at a fundamental resonance frequency of $f$, which irritates his customers. In an attempt to fix the problem, the shop owner cuts the wire in half and hangs the sign from the two halves, as shown in the right part of the figure. Assuming the tension in each of the two wires is now half the original tension, what is the new fundamental frequency of each wire?

D

At fundamental vibration,

$L = \frac{1}{2}\lambda$, $f = \frac{v}{\lambda} = \frac{v}{2L}\sqrt{\frac{T}{\mu}}$




$f_{new} = \frac{v}{2L_{new}}\sqrt{\frac{T_{new}}{\mu}}$

$f_{new} = \frac{v}{2(\frac{L}{2})}\sqrt{\frac{T/2}{\mu}}$

$f_{new} = 2\left(\frac{v}{2L}\right)\frac{1}{\sqrt{2}}\sqrt{\frac{T}{\mu}} = \sqrt{2}\cdot f$

(A) $\frac{f}{2}$ (B) $\frac{f}{\sqrt{2}}$ (C) $f$ (D) $\sqrt{2}f$ (E) $2f$

A7. A light ray travels through water (index of refraction of 1.333) and strikes a water-air boundary at an angle of incidence of 54.7°. Which one of the following statements is correct regarding the path(s) of light at the water-air boundary?

A

(A) The light ray totally internally reflects. All the light remains in the water.
(B) Some of the light reflects and some of the light refracts into the air. The angle of refraction is greater than the angle of incidence.
(C) Some of the light reflects and some of the light refracts into the air. The angle of refraction is less than the angle of incidence.
(D) All of the light refracts into the air. None of the light is reflected.
(E) The light is completely absorbed at the water-air boundary.

$\theta_1 = \theta_c$ when $\theta_2 = 90°$   $n_1 \sin\theta_c = n_2 \Rightarrow \theta_c = \arcsin\left(\frac{n_2}{n_1}\right) = \arcsin\left(\frac{1}{1.333}\right)$

$\theta_c = 48.6°$   Since $\theta_1 > \theta_c$, total internal reflection occurs.

A8. An object is placed 5.00 cm in front of a diverging lens with a focal length of magnitude of 7.50 cm. Which one of the following statements is correct?

A

(A) The image is upright and smaller than the object. – always, regardless of position of real object relative to focal point.
(B) The image is upright and larger than the object.
(C) The image is inverted and smaller than the object.
(D) The image is inverted and larger than the object.
(E) The image is inverted and exactly the same size as the object.

A9. Which one of the following statements is true regarding electromagnetic (EM) waves traveling through a vacuum?

C

(A) All EM waves have the same wavelength.
(B) All EM waves have the same frequency.
(C) All EM waves travel at a speed of $c$ in a vacuum.
(D) The electric field associated with the wave is parallel to the velocity of the wave.
(E) The magnetic field associated with the wave is parallel to the velocity of the wave.

A10. In a Young's double-slit interference apparatus, by what factor is the distance between adjacent bright and dark fringes changed when the separation between the slits is doubled?

B

(A) ¼ (B) ½ (C) 1 (D) 2 (E) 4

$d \sin\theta_{bright} = m\lambda$ ; $\sin\theta_{bright} = \frac{m\lambda}{d}$ ; for small angles $\theta_{bright} \propto \frac{1}{d}$

A11. You wish to design a simple magnifier that has the largest possible angular magnification. You have a choice of two converging lenses, the focal length of lens 1 is less than the focal length of lens 2. Which one of the following setups will satisfy your design goal?

C

(A) Use lens 1 and place the object at the near point of the person using the magnifier.
(B) Use lens 2 and place the object at the near point of the person using the magnifier.
(C) Use lens 1 and place the object so that the image formed by the lens is at the near point of the person using the magnifier.
(D) Use lens 2 and place the object so that the image formed by the lens is at the near point of the person using the magnifier.
(E) Use lens 1 and place the object so that the image formed by the lens is at the far point of the person using the magnifier.

$m = \frac{N}{p} = N\left(\frac{1}{f} - \frac{1}{q}\right) \Rightarrow m_{max} = N\left(\frac{1}{f} - \frac{1}{-N}\right) = \frac{N}{f} + 1$

A12. Which one of the following statements correctly describes the process by which the human eye adjusts to maintain focus on an object that is approaching the eye?

A

(A) The focal length of the eye lens becomes shorter.
(B) The focal length of the eye lens becomes longer.
(C) The lens-retina distance increases.
(D) The lens-retina distance decreases.
(E) The diameter of the pupil increases.

$q_{eye}$ is fixed.

$q_{eye} = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1}$

∴ as $p\downarrow$ (object approaching), $f$ must decrease as well

A13. The diffraction grating in a spectrometer has $N$ slits/cm. The spectrometer is being used to observe light of wavelength $\lambda$. For the light forming the second order maximum (bright spot), which one of the following options is correct for the difference in the distance that the light has travelled from consecutive slits?

D

(A) $N\lambda$ (B) ½ $\lambda$ (C) $\lambda$ (D) $2\lambda$ (E) $\lambda/N$

2nd order maximum means path length difference is $2\lambda$

A14. Two cylinders A and B at the same temperature contain the same quantity (number of molecules) of the same kind of gas. Cylinder A has three times the volume of cylinder B. What can you conclude about the pressures the gases exert?

C

Ideal Gas Law

$PV = NkT$

$P = \frac{NkT}{V}$

(A) We can conclude nothing about the pressures.
(B) The pressure in cylinder A is one-ninth the pressure in cylinder B.
(C) The pressure in cylinder A is one-third the pressure in cylinder B.
(D) The pressure in cylinder A is three times the pressure in cylinder B.
(E) The pressure in cylinder A is nine times the pressure in cylinder B.

$N, T$ unchanged, $P \propto \frac{1}{V}$

A15. A steel tank is completely filled with gasoline when the temperature is 20°C. The coefficient of volume expansion of gasoline is greater than the coefficient of volume expansion of steel. What happens when the temperature drops to 15°C?

A

The gasoline contracts more than the steel tank.

(A) The tank will no longer be completely filled.
(B) The tank will still be completely filled, with no spillage of gasoline from the tank.
(C) Some of the gasoline will overflow from the tank.
(D) Nothing can be determined without knowing the volume of the tank.
(E) Nothing can be determined without knowing the values of the volume expansion coefficients.

A16. A window conducts energy from a house to the cold outdoors at a rate $P$. At what rate is energy conducted through a window of half the area and twice the thickness? (Assume that both windows are made of the same type of glass.)

E

(A) $4P$ (B) $2P$ (C) $P$ (D) ½ $P$ (E) ¼ $P$

$P_1 = \frac{kA_1(T_h - T_c)}{L_1}$ ; $P_2 = \frac{k(\frac{1}{2}A_1)(T_h - T_c)}{2L_1} = \frac{1}{4}P_1$

A17. An object emits thermal radiation at a rate of $P_1$ when its temperature is 273°C. The temperature of the object then increases to 546°C. What can be said about the new rate of thermal radiation emission, $P_2$?

D

(A) $P_2 = P_1$ (B) $P_2 = 1.5P_1$ (C) $P_2 = 2P_1$ (D) $P_2 = 5.06P_1$ (E) $P_2 = 16P_1$

$P = \sigma A e T^4$ $\frac{P_2}{P_1} = \frac{T_2^4}{T_1^4} = \frac{(546+273)^4}{(273+273)^4} = 5.06$

A18. If a material has a work function $\phi$, the threshold wavelength for the photoelectric effect to occur in this material is given by:

C

(A) $\dfrac{\phi}{hc}$ (B) $hf$ (C) $\dfrac{hc}{\phi}$ (D) $\dfrac{\phi}{e}$ (E) $\dfrac{\phi}{hf}$

$KE_{max} = 0$ at threshold $\Rightarrow$ $0 = \frac{hc}{\lambda} - \phi \Rightarrow \lambda = \frac{hc}{\phi}$

A19. In the Compton effect, a photon of wavelength $\lambda$ and frequency $f$ collides with an electron that is initially at rest. Which one of the following occurs as a result of the collision?

D

(A) The photon is absorbed completely.
(B) The photon gains energy, so the final photon has a frequency greater than $f$.
(C) The photon gains energy, so the final photon has a wavelength greater than $\lambda$.
(D) The photon loses energy, so the final photon has a frequency less than $f$.
(E) The photon loses energy, so the final photon has a wavelength less than $\lambda$.

photon loses energy. $E_\gamma = hf = \frac{hc}{\lambda} \Rightarrow f\downarrow, \lambda\uparrow$

A20. Calculate the energy of the photon emitted when an electron makes a transition from the $n = 3$ to the $n = 2$ quantum state of Hydrogen.

D

(A) 4.91 eV (B) 2.27 eV (C) 1.51 eV (D) 1.89 eV (E) 3.40 eV

$E_{photon} = E_3 - E_2 = -13.6\text{eV}\left(\frac{1}{3^2} - \frac{1}{2^2}\right) = 1.89\text{eV}$

**PART B**

**WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.**

**YOU MAY ANSWER ALL SIX PART B QUESTION GROUPINGS (21-24, 25-28, 29-32, 33-36, 37-40, AND 41-44) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 5 GROUPINGS.**

**USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK. WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).**

**IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE HALF-MARKS (1/2).**

**IF YOU STILL DO NOT HAVE THE CORRECT ANSWER, BUT RE-WORK YOUR SOLUTION AND REVEAL A STAR WITH YOUR THIRD SCRATCH, THEN YOU RECEIVE 0.2/2.**

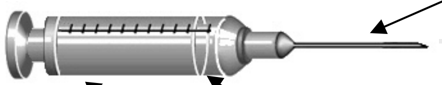
**REVEALING THE STAR WITH YOUR FOURTH OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.**

B21. Consider two pipelines carrying the same viscous fluid. The situations are identical except that one pipeline has a radius that is twice that of the other. Let $Q$ be the volume flow rate in the smaller pipeline. The volume flow rate in the larger pipeline is...

16$Q$

$$Q = \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8 \eta L} \quad ; \quad Q \propto R^4$$

A hypodermic syringe is attached to a needle that has an internal radius of 0.30000 mm and a length of 3.0000 cm. The needle and syringe are filled with a solution of viscosity 2.0000 × $10^{-3}$ Pa·s and density 1.1000 × $10^3$ kg/$m^3$. Initially, the pressure of the fluid in the syringe is 1.0130 × $10^5$ Pa. The solution is to be injected into a vein where the pressure is 1.0343 × $10^5$ Pa.




B22. Calculate the pressure of the fluid in the syringe that is required in order to inject solution into the vein at a rate of 2.5000 × $10^{-7}$ $m^3$/s. *Express your answer to 5 significant figures.*

Viscous flow $\Rightarrow \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8 \eta L} \Rightarrow \frac{8 \eta L (\Delta V / \Delta t)}{\pi R^4} = P_1 - P_2$

$$P_1 = \frac{8 \eta L (\Delta V / \Delta t)}{\pi R^4} + P_2 = \frac{8 (2.0000 \times 10^{-3}\ Pa \cdot s)(3.0000 \times 10^{-2}\ m)(2.5000 \times 10^{-7}\ m^3/s)}{\pi (0.30000 \times 10^{-3}\ m)^4}$$

$$+ 1.0343 \times 10^5\ Pa$$

$$P_1 = 1.08146 \times 10^5\ Pa$$

B23. If the cross-sectional area of the syringe is 1.0000 $cm^2$, calculate the external force that must be applied to the plunger by the person injecting the solution, in order to obtain the desired pressure of the fluid in the syringe. i.e. Calculate the force with which the person must push the plunger.

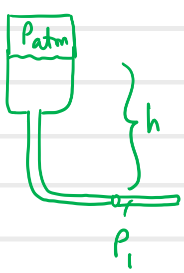
Initial pressure in syringe is $P_{atm} = 1.0130\times10^5\ Pa$

Want $P = P_1 = 1.08146\times10^5\ Pa$

$$\therefore\quad P_{atm} + \frac{F}{A} = P_1 \Rightarrow \frac{F}{A} = P_1 - P_{atm} \Rightarrow F = (P_1 - P_{atm})A$$

$$F = (1.08146\times10^5\ Pa - 1.0130\times10^5\ Pa)(1.0000\,cm^2)\left(\frac{1\,m}{100\,cm}\right)^2 = 0.685\,N$$

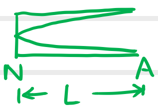
B24. Now suppose that the fluid is to be delivered by a tube connected to an elevated bottle rather than by a hypodermic syringe. Calculate the required height of the fluid in the bottle relative to the fluid in the needle in order to obtain the pressure calculated in B22. You may assume that the surface of the fluid in the bottle is at atmospheric pressure and you may ignore any viscous effects in the tube.




$$P_1 = P_{atm} + \rho g h \Rightarrow h = \frac{P_1 - P_{atm}}{\rho g} = \frac{6.846\times10^3\ Pa}{(1.1000\times10^3\,\frac{kg}{m^3})(9.80\,m/s^2)}$$

$$h = 0.635\,m$$

B25. Consider a pipe of length $L$ that is open at one end and closed at the other. Let $\upsilon$ represent the speed of sound in air. Which one of the following is the correct expression for the fundamental frequency of standing waves in the pipe?




$\Rightarrow \frac{1}{4}\lambda = L \Rightarrow \lambda = 4L \; ; \; f = \frac{\upsilon}{\lambda} = \frac{\upsilon}{4L}$

Two pipes of equal length of 25.3 cm, that are each open at one end and closed at the other, are placed side-by-side.

B26. If the intensity level at a distance of 5.00 m from the pipes is 55.0 dB when both pipes are producing the same power of sound, what would be the intensity level if only one pipe is producing sound?

$P_2 = \frac{1}{2}P_1 \Rightarrow I_2 = \frac{1}{2}I_1 \; ; \; \beta_2 = 10\log\left(\frac{I_2}{I_0}\right) = 10\log\left(\frac{\frac{1}{2}I_1}{I_0}\right) = 10\left[\log\left(\frac{1}{2}\right) + \log\left(\frac{I_1}{I_0}\right)\right]$

$\beta_2 = 10\log\left(\frac{1}{2}\right) + 10\log\left(\frac{I_1}{I_0}\right) = -3.01\,dB + \beta_1 = -3.01\,dB + 55.0\,dB = 52.0\,dB$

Long method: $I_1 = I_0 \times 10^{\beta_1/10} = (1.00\times10^{-12}\,W/m^2)\times 10^{5.5} = 3.162\times10^{-7}\,W/m^2$

$I_2 = \frac{1}{2}I_1 = 1.581\times10^{-7}\,W/m^2 \Rightarrow \beta_2 = 10\log\left(\frac{1.581\times10^{-7}\,W/m^2}{1.00\times10^{-12}\,W/m^2}\right) = 52.0\,dB$

B27. Calculate the speed of sound in each pipe when the air temperature is 27.0°C.

$\upsilon = 331\,m/s\sqrt{\frac{273+27.0}{273}} = 347\,m/s$

B28. Both pipes are producing sound at the fundamental frequency. If the air temperature in one pipe increases to 32.0°C while the air temperature in the other pipe remains at 27.0°C, what will be the beat frequency (approximately)?

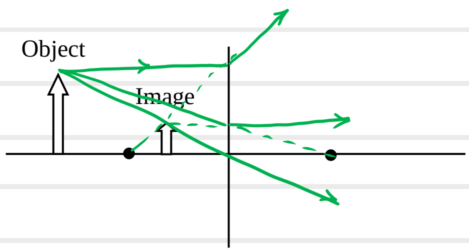
$\upsilon_{32} = 331\,m/s\sqrt{\frac{273+32}{273}} = 350\,m/s \; ; \; f = \frac{\upsilon}{4L}$

$f_{beat} = f_1 - f_2 = \frac{1}{4L}(\upsilon_1 - \upsilon_2) = \frac{1}{4(0.253\,m)}(350\,m/s - 347\,m/s) = 3\,Hz$

B29. Which one of the following options is possible with regard to the image size and orientation when using a single **converging** lens? ("upright" means image orientation the same as that of the object, "inverted" means image orientation opposite that of the object)

upright image, larger than object, on same side of lens as object

B30. Which one of the following diagrams correctly shows the location of the image when an object is placed in front of a single **diverging** lens?




B31. An object is placed 20.0 cm to the left of a diverging lens whose focal points are 30.0 cm from the lens. Calculate the magnification and the distance of the image from the diverging lens.

$p = +20.0\,\text{cm}$, $f = -30.0\,\text{cm}$ (diverging lens)

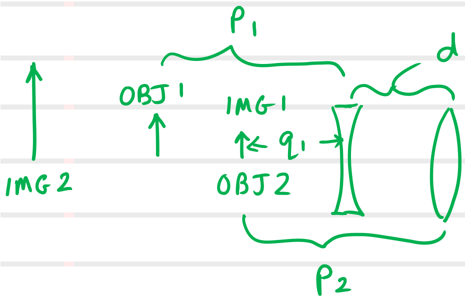
$$q = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \left(\frac{1}{-30.0\,\text{cm}} - \frac{1}{+20.0\,\text{cm}}\right)^{-1} = -12.0\,\text{cm}$$

b/w object and lens ✓

$$M = -\frac{q}{p} = -\frac{(-12.0\,\text{cm})}{+20.0\,\text{cm}} = +0.600$$

upright ✓ smaller ✓

B32. A converging lens whose focal points are 30.0 cm from the lens is now added to the setup described in B31. The converging lens is placed 5.00 cm to the right of the diverging lens. Calculate the location of the final image relative to the converging lens.




$p_2 = |q_1| + d = |-12.0\text{cm}| + 5.00\text{cm}$

$p_2 = +17.0\text{ cm}$

$q_2 = \left(\frac{1}{f_2} - \frac{1}{p_2}\right)^{-1} = \left(\frac{1}{+30.0\text{cm}} - \frac{1}{+17.0\text{cm}}\right)^{-1}$

$q_2 = -39.2\text{ cm}$ ← to left of converging lens

In a double-slit experiment, a laser emits monochromatic light which is incident upon two slits that are separated by a distance of 0.0800 mm. The width of each slit is 0.0100 mm.

B33. Which one of the following statements correctly describes the appearance of the fringe pattern on a screen?

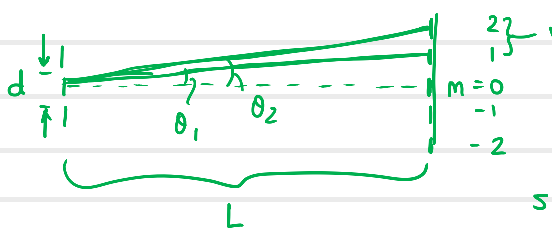
The centre of the pattern is a bright fringe, and subsequent bright fringes decrease in intensity as you look further away from the centre of the pattern, eventually reaching a minimum intensity determined by the width of the slits.

B34. The first point of destructive interference occurs at an angle of 0.226° with respect to the direction of the incident light. Calculate the wavelength of the laser light.

$d \sin\theta_{dark} = (m + \frac{1}{2})\lambda$ ; $m = 0$ for 1ST dark fringe $\Rightarrow$ $d \sin\theta_{dark_1} = \frac{1}{2}\lambda$

$\lambda = 2d \sin\theta_{dark_1} = 2(0.0800 \times 10^{-3} m)\sin(0.226°) = 6.31 \times 10^{-7} m = 631 \text{ nm}$

B35. The double-slit interference pattern appears on a screen that is a distance of 15.0 m from the slits. Calculate the separation distance between the first- and second-order bright fringes (locations of constructive interference) on the screen.




$\sin\theta_2 = \frac{2\lambda}{d} \simeq \tan\theta_2 = \frac{y_2}{L}$

$\therefore y_2 = \frac{2\lambda L}{d}$

$\sin\theta_1 = \frac{\lambda}{d} \simeq \tan\theta_1 = \frac{y_1}{L} \Rightarrow y_1 = \frac{\lambda L}{d}$

$y_2 - y_1 = \frac{2\lambda L}{d} - \frac{\lambda L}{d} = \frac{\lambda L}{d} = \frac{(6.31 \times 10^{-7} m)(15.0 m)}{0.0800 \times 10^{-3} m} = 0.118 m = 11.8 cm$

B36. One of the slits is now blocked, but light continues to pass through the other slit. Calculate the position on the screen, relative to the central maximum, of the position of the first minimum of intensity.

Now have single-slit diffraction

$$\sin\theta_{dark} = \frac{m\lambda}{a} \Rightarrow \sin\theta_{dark,1} = \frac{\lambda}{a}$$

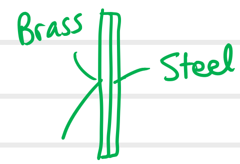
$$\theta_{dark,1} = \arcsin\left(\frac{\lambda}{a}\right) = \arcsin\left(\frac{6.31\times10^{-7}\,m}{0.0100\times10^{-3}\,m}\right) = 3.618^\circ$$ ($< 12^\circ$, ∴ small angle approx. still valid)

$$\sin\theta_{dark,1} \simeq \tan\theta_{dark,1} = \frac{y_{min,1}}{L}$$

$$y_{min,1} = \frac{L\lambda}{a} = \frac{15.0\,m\,(6.31\times10^{-7}\,m)}{0.0100\times10^{-3}\,m} = 0.947\,m$$

B37. The coefficient of thermal expansion for brass is greater than for steel. Consider a bimetallic strip made of brass on the left and steel on the right. The strip is fixed in place at its bottom and its top end is free to move. If the strip is straight at room temperature, what happens to the strip at temperatures below room temperature?

The top end of the strip bends to the left.




Contracts more when cooled.

A metal ring with a coefficient of thermal expansion of $\alpha_1$ has a diameter of 10.00 cm at 20.0°C. The ring is then heated to 155°C and placed over a rod made of a metal with a coefficient of thermal expansion of $\alpha_2$ and diameter 10.01 cm at 20.0°C.

B38. If the change in the diameter of the ring between 20.0°C and 155°C is 0.0162 cm, calculate the coefficient of thermal expansion of the ring.

$$\Delta L = \alpha L_0 \Delta T \Rightarrow \alpha = \frac{\Delta L}{L_0 \Delta T} = \frac{0.0162\text{ cm}}{(10.00\text{cm})(155°\text{C} - 20.0°\text{C})}$$

$$\alpha = 1.20 \times 10^{-5}/°\text{C} = 12.0 \times 10^{-6}/°\text{C}$$

B39. If the coefficient of thermal expansion of the rod, $\alpha_2$, is twice that of the ring, i.e. if $\alpha_2 = 2\alpha_1$, then calculate the temperature to which the ring and rod system must be cooled so that the ring can be removed from the rod.

At new final temp, want $d_2 = d_1 \Rightarrow d_{20} + d_{20}\alpha_2 \Delta T = d_{10} + d_{10}\alpha_1 \Delta T$

$$d_{20} - d_{10} = (d_{10}\alpha_1 - d_{20}\alpha_2)\Delta T \Rightarrow \Delta T = \frac{d_{20} - d_{10}}{d_{10}\alpha_1 - d_{20}\alpha_2}$$

$$\Delta T = \frac{10.01\text{ cm} - 10.00\text{ cm}}{(10.00\text{cm})(12 \times 10^{-6}/°\text{C}) - (10.01\text{ cm})(24 \times 10^{-6}/°\text{C})} = -83.16°\text{C} = T_2 - T_1$$

$$T_2 = -83.16°\text{C} + T_1 = -83.16°\text{C} + 20.0°\text{C} = -63.2°\text{C}$$

B40. The mass of the rod is 0.350 kg. As soon as the ring has been removed from the rod, the rod is put in an aluminum container that is filled with water. The mass of the aluminum container is 0.400 kg and the mass of the water is 0.250 kg. The initial temperature of the rod is the value calculated in B39 and the initial temperature of the aluminum container and the water inside is 25.0°C. The specific heat of the rod is 448 J/kg·°C, the specific heat of aluminum is 901 J/kg·°C, and the specific heat of water is 4186 J/kg·°C. Calculate the final temperature of the rod-aluminum-water system. You may assume that there is no energy transferred to the surroundings.

$$\Sigma Q_i = 0 \Rightarrow Q_{rod} + Q_{Al} + Q_w = 0$$

$$m_r c_r \Delta T_r + (m_{Al} c_{Al} + m_w c_w)\Delta T_{Al,w} = 0$$

$$m_r c_r (T_f - T_r) + (m_{Al} c_{Al} + m_w c_w)(T_f - T_{Al,w}) = 0$$

$$(m_r c_r + m_{Al} c_{Al} + m_w c_w) T_f = m_r c_r T_r + (m_{Al} c_{Al} + m_w c_w) T_{Al,w}$$

$$T_f = \frac{m_r c_r T_r + (m_{Al} c_{Al} + m_w c_w) T_{Al,w}}{m_r c_r + m_{Al} c_{Al} + m_w c_w}$$

$$T_f = \frac{(0.350\,kg)(448\,J/kg\cdot°C)(-63.2°C) + \left[(0.400\,kg)(901\,J/kg\cdot°C) + (0.250\,kg)(4186\,J/kg\cdot°C)\right]\cdot 25.0°C}{(0.350\,kg)(448\,J/kg\cdot°C) + (0.400\,kg)(901\,J/kg\cdot°C) + (0.250\,kg)(4186\,J/kg\cdot°C)}$$

$$T_f = 16.2°C$$

B41. Which one of the following statements regarding the nucleus is **FALSE**?

The mass density of the nucleus is the same as the mass density of the atom. ×

The isotope $^{60}_{27}Co$ has an atomic mass of 59.933819 u.

B42. Calculate the binding energy of this isotope.

$$BE = (\Delta m)c^2 = (Zm_H + Nm_n - M_{atomic})c^2$$

$$BE = (27(1.007825u) + 33(1.008665u) - 59.933819u) \times 931.494\ MeV/u = 525\ MeV$$

B43. The $^{60}_{27}Co$ isotope is radioactive and decays into $^{60}_{28}Ni$. Which one of the following particles is emitted during this decay?

$$^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^{0}_{-1}? + ? \Rightarrow {}^{0}_{-1}? = \text{electron and } ? = \text{antineutrino}$$

B44. A sample of $^{60}_{27}Co$ contains $5.00 \times 10^{21}$ nuclei. Exactly one year later, the number of $^{60}_{27}Co$ nuclei in the sample is $4.38 \times 10^{21}$. Calculate the half-life of $^{60}_{27}Co$.

$N_0 = 5.00 \times 10^{21}$ ; $N = 4.38 \times 10^{21}$ when $t = 1$ yr.

$$N = N_0 e^{-\lambda t} \Rightarrow \frac{N}{N_0} = e^{-\lambda t} \Rightarrow \ln\left(\frac{N}{N_0}\right) = -\lambda t \Rightarrow \lambda = -\frac{1}{t}\ln\left(\frac{N}{N_0}\right)$$

$$\lambda = -\frac{1}{1\ yr}\ln\left(\frac{4.38}{5.00}\right) = 0.1324/yr \Rightarrow T_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{0.1324/yr}$$

$$T_{1/2} = 5.24\ y$$

***END OF EXAMINATION***