Review Session

Friday, March 15, 2019 11:06 AM

Determine the number of degrees of freedom in each of this cases:

a) A diatomic gas where the vibrational degrees of freedom are frozen out.
5, 3 translation + 2 rotation

b) A monatomic gas.
3 translation only

c) A diatomic gas where the rotational and vibrational degrees of freedom are frozen out.
3 translation only

You are doing x-ray diffraction on a crystal that has a cubic structure, using 0.430-nm x rays. The lattice spacing is d = 6.70×10^{-10} m

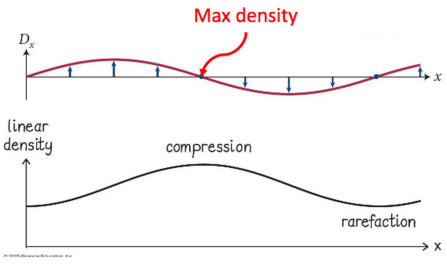
What is the greatest Bragg angle at which you observe peaks in the intensity of the diffracted rays?

What is the second greatest Bragg angle at which you observe peaks in the intensity of the diffracted rays?

Sound waves consist of longitudinal waves propagating through any kind of material. The diagram shows the displacement of air molecules in a sound wave traveling through air in the x direction. On the diagram indicate an x position where the density of the air molecules is maximum.

The air molecules to the left of the location of maximum density are displaced to the right.

The air molecules to the right of the location of maximum density are displaced to the left.



A thermally insulated box contains gas in thermal equilibrium. The box is split into two compartments with 2/3rd of the gas particles in compartment A (system A) and the rest of the gas in compartment B (system B). The partition between the compartments is free to move, and initially the volume of compartment B is 3 times the volume of compartment A. Which of the following is/are correct? Select all that apply.

A. The entropy of system A increases.
B. The entropy of system A decreases.
C. The entropy of system A does not change.
D. The entropy of system B increases.
E. The entropy of system B decreases.
F. The entropy of system B does not change.

A thermally insulated box contains gas in thermal equilibrium. The box is split into two compartments with 2/3rd of the gas particles in compartment A (system A) and the rest of the gas in compartment B (system B). The partition between the compartments is free to move, and initially the volume of compartment B is 3 times the volume of compartment A. Which of the following is/are correct? Select all that apply.

A. The entropy of system A increases.
B. The entropy of system A decreases.
C. The entropy of system A does not change.
D. The entropy of system B increases.
E. The entropy of system B decreases.
F. The entropy of system B does not change.
G. The entropy of the combined (A+B) system increases.
H. The entropy of the combined (A+B) system decreases.
I. The entropy of the combined (A+B) system does not change.

∵ thermally insulated
∴ T const.

$\Delta S = N \cdot \ln\left(\frac{V_f}{V_i}\right)$

∴ AEG

$\Delta S_A = \frac{2}{3} \cdot \ln\left(\frac{2}{3} \cdot \frac{4}{1}\right) = 0.65$

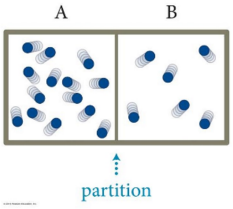
$\Delta S_B = \frac{1}{3} \ln\left(\frac{1}{3} \cdot \frac{4}{3}\right) = -0.27$

$\Delta S_{sys} = 0.65 - 0.27 > 0$ or sys is thermally insulated, goes to eq leads to $\Delta S > 0$

Quiz: Thermal equilibrium

Consider a closed system of two monatomic gases that can exchange energy with each other as shown. There are 14 gas molecules in compartment A and 6 in compartment B. Each gas molecule has a mass of 5.0×10^{-26} kg. The gas molecules in compartment A have a thermal energy of 8.4×10^{-20} J and those on compartment B have a thermal energy 7.0×10^{-20} J. At thermal equilibrium what is the thermal energy in compartment A?

Enter answer in J, but only enter the number.
Use notation 1.0E-30 for 1.0×10^{-30}



$\frac{E_{thA}}{N_A} = \frac{E_{thB}}{N_B}$ ← Eth for each particle should equal at eq. $\Rightarrow E_{thBf} = \frac{N_B}{N_A} E_{thAf}$

$E_{th} = E_{thAi} + E_{thBi} = E_{thAf} + E_{thBf}$

$15.4 \times 10^{-20} = \frac{6}{14} E_{thAf} + E_{thAf}$

$E_{thAf} = 15.4 \times 10^{-20} \times \frac{14}{6+14} = 10.78 \times 10^{-20}$ J

$E_{th} = \frac{3}{2} N k_B T = E_{thA} + E_{thB}$

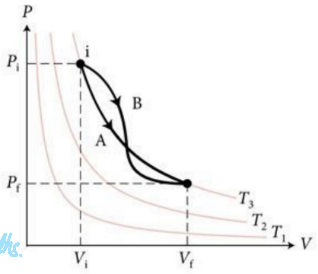
T equals, ← temperature equals at eq.

$\frac{E_{thA}}{E_{thB}} = \frac{N_A}{N_B}$

then also plug-in.

The figure shows two processes, A and B, carried out on an ideal gas. Compare the change in thermal energy and change in entropy of the two processes.

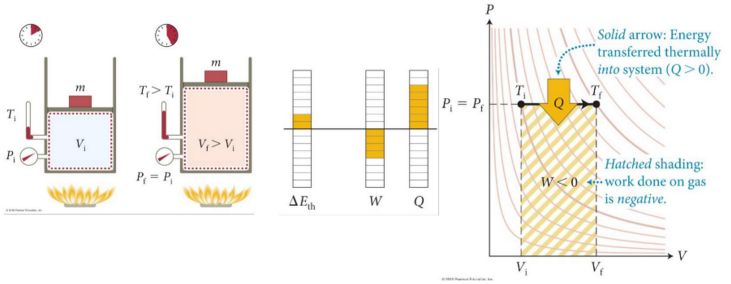
A. $\Delta E_{\text{th,A}} = \Delta E_{\text{th,B}}$
B. $\Delta E_{\text{th,A}} > \Delta E_{\text{th,B}}$
C. $\Delta E_{\text{th,A}} < \Delta E_{\text{th,B}}$
D. $\Delta S_{\text{A}} = \Delta S_{\text{B}}$
E. $\Delta S_{\text{A}} > \Delta S_{\text{B}}$
F. $\Delta S_{\text{A}} < \Delta S_{\text{B}}$



Just notice that ΔEth, ΔS are independent on paths.

An ideal gas is in a chamber with a plunger on top. While a constant force is applied to the plunger the chamber is heated by a flame. Which of the following statements are correct?

A. $\Delta E_{\text{th}} > 0$
B. $\Delta E_{\text{th}} < 0$
C. $\Delta E_{\text{th}} = 0$
D. $W > 0$
E. $W < 0$
F. $W = 0$
G. $Q > 0$
H. $Q < 0$
I. $Q = 0$



This is an isobaric process, so $W = -P\Delta V$. From the ideal gas law ($PV = Nk_{\text{B}}T$) we can write this as $W = -Nk_{\text{B}}\Delta T$. From the definition of C_{P} we get $Q = NC_P\Delta T$. For an ideal gas $\Delta E_{\text{th}} = NC_V\Delta T$.

If can't determine it by equation, then try to draw PV-diagram.

Tutorial & lab summery

Thursday, March 21, 2019 9:16 AM

- For double slit interference, if the width of one of the slits were decreased, nodal lines disappear, antinodal lines keep in their previous position but decrease in amplitude.

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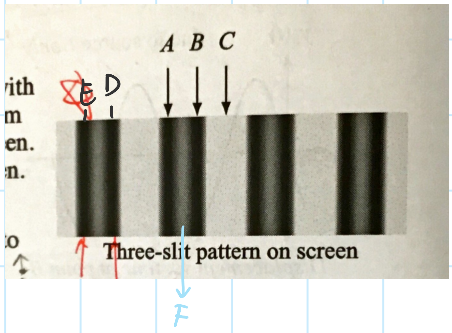


$\delta\varphi_{adj}$ for point B: $\frac{1}{3}\lambda \cdot \frac{2\pi}{\lambda} = \frac{2}{3}\pi$

$\delta\varphi_{adj}$ for point A: $\frac{2}{3}\pi \cdot \frac{2\pi}{\lambda} = \frac{4}{3}\pi$

$\delta\varphi_{adj}$: distance between adjacent phasors.

$\delta\varphi_{adj}$ for point E:

$\delta\varphi_{adj}$ for point D:

- $\delta\varphi_{adj}$ for F: $\frac{\delta s_A + \delta s_B}{2} \cdot \frac{2\pi}{\lambda} = \frac{1.5\lambda}{3} \cdot \frac{2\pi}{\lambda} = \pi$

Ratio of I on the screen compared to I of a principal maximum: 1:9

(I is proportional to D_y^2 of a wave) D_y: maximum transverse displacement of a wave.

- Formula for single slit: $D\sin\theta = m\lambda$

- Decrease the width of the slit, the intensity shown on the screen decreases, ∵ slit behave more and more like a point source

✡ Lab

- Lens-maker's equation (calculate the f of double convex lens)

$$\frac{1}{f} = (n_{lens} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

  - R "+" if the center of curvature is on the refracted-light side (R_1 +, R_2 - for above)
    "−" otherwise.

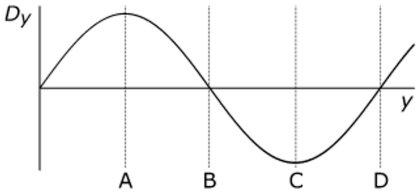
- Angular size given by lens.
  - Lens with shorter f gives a larger angular size.
  - Lens position with nearer to focus gives a larger angular size.

Probs

Saturday, March 16, 2019 10:34 AM

★★★★

6. (6 points) The figure shows the displacement of air molecules in a sound wave as a function of position at a moment in time. At the instance shown, where is the pressure of the air maximum?



A) Point A
B) Point B
C) Point C
D) Point D
E) Points B and D

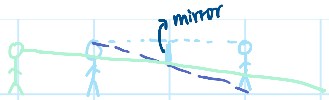
Notice that vertical & horizontal are both y. B

So Dy left of B >0, tends to go to B, Dy right of B<0, also goes to B

★★

9. (6 points) A person stands 2.0 m in front of a vertical mirror that is just tall enough for them to see the top of their head and their feet. In which of the following positions can the person stand and still see their head and feet?

A) They can stand 1.0 m from the mirror and still see their head and feet
B) They can stand 4.0 m from the mirror and still see their head and feet
C) Both A and B are true
D) Neither A nor B are true
E) More information is required



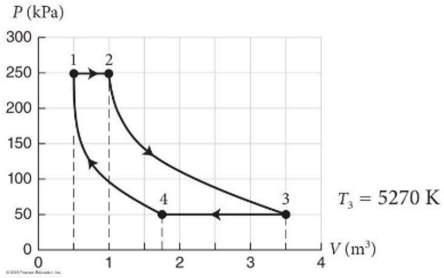
No matter where they stand, always be a 1:1 distance, 1:2 height.

C

★★★★

Use the following situation for the next two problems.

An engine undergoes a Brayton cycle as shown in the *PV* diagram. During a complete cycle the work done **by** the gas is 169×10^3 J and the energy transferred thermally out is 393×10^3 J. There are 2.4×10^{24} gas molecules and they have **seven** active degrees of freedom.



21. (6 points) How much work is done **by** the gas during process 2 → 3?

isentropic, Q=0 ∴ ΔEth = W

$P_2V_2 = Nk_BT_2 \Rightarrow \frac{2.5\times10^5\times1}{24\times1.381} = T_2 = 7543$

A) 112×10^3 J
B) 187×10^3 J
C) 219×10^3 J
D) 224×10^3 J
E) 262×10^3 J

$W = \Delta E_{th} = NC_V\Delta T = 24\times1.381\times\frac{7}{2}\times(7543-5270) = 262\times10^3$ J

22. (6 points) What is the efficiency of the heat engine?

$\eta = -\frac{W}{Q_{in}} = -\frac{W}{|W|+|Q_{out}|}$

$= 0.3$

A) 0.30
B) 0.43
C) 0.50
D) 0.65
E) 0.75

★★★

5. (6 points) Two guitar strings are under the same tension and fixed with the same length at both ends (nut and bridge). If you pluck the strings in exactly the same way, string 1 produces a lower-pitched note than string 2. What can you conclude about the wave speeds in strings 1, c_1, and 2, c_2, and the wavelengths in strings 1, λ_1, and 2, λ_2?

$c = \sqrt{\frac{T}{\mu}} = \lambda f$

$\lambda_1 = \lambda_2 = 2L$ (first harmonic)

$f_1 < f_2$

A) $c_1 = c_2$ and $\lambda_1 > \lambda_2$
B) $c_1 = c_2$ and $\lambda_1 < \lambda_2$

5. (6 points) Two guitar strings are under the same tension and fixed with the same length at both ends (nut and bridge). If you pluck the strings in exactly the same way, string 1 produces a lower-pitched note than string 2. What can you conclude about the wave speeds in strings 1, c_1, and 2, c_2, and the wavelengths in strings 1, λ_1, and 2, λ_2?

A) $c_1 = c_2$ and $\lambda_1 > \lambda_2$
B) $c_1 = c_2$ and $\lambda_1 < \lambda_2$
C) $c_1 = c_2$ and $\lambda_1 = \lambda_2$
D) $c_1 < c_2$ and $\lambda_1 = \lambda_2$
E) $c_1 > c_2$ and $\lambda_1 = \lambda_2$

$c = \sqrt{\frac{T}{\mu}} = \lambda f$ $\quad \lambda_1 = \lambda_2 = 2L$ (first harmonic)
$f_1 < f_2$
$\therefore c_1 < c_2$
D

8. (6 points) One way to tune a piano is to strike a tuning fork, which emits note of frequency 261.626 Hz, then immediately strike the piano key for the frequency being sounded by the fork, and listen for beats. A beat frequency of 1.60 Hz is heard, what should you do?

A) Increase the tension in the string by 0.61%
B) Decrease the tension in the string by 0.61%
C) Increase the tension in the string by 1.2%
D) Decrease the tension in the string by 1.2%
E) Either C or D

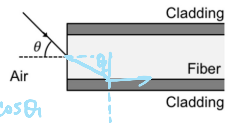
$c = \sqrt{\frac{T}{\mu}}$
$\left(1 \pm \frac{1.6}{261.626}\right)^2 - 1^2 = \pm 1.2\%$
E
Be careful of the calculation here.

7. (6 points) Suppose you are standing 12 m away from a speaker that produces a sound in all directions uniformly. The intensity level of the sound you hear is 32 dB. If you move so that the intensity level of the sound you hear is now 64 dB, how far away are you from the speaker?

A) 7.6×10^{-3}m
B) 0.30 m
C) 4.8 m
D) 6.0 m
E) 24 m

$\beta = 10\log\left(\frac{P}{A \cdot 10^{-12}}\right)$
$10^{3.2} \times 10^{-12} = \frac{P}{4\pi \cdot 12^2}$
$P = 4\pi \times 12^2 \times 10^{-12} \times 10^{3.2}$
$10^{6.4} \times 10^{-12} = \frac{P}{4\pi r^2}$
$r^2 = \frac{P}{4\pi \cdot 10^{6.4} \times 10^{-12}}$
$r^2 = \frac{12^2 \times 10^{3.2}}{10^{6.4}} = 0.09\,m$
$r = 0.3m$

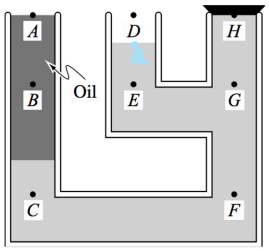
trap!
9. (6 points) Suppose that optical fiber with an index of refraction of 1.7 is surrounded by a cladding material with an index of refraction of 1.4. What is the maximum angle θ at which rays can enter the fiber from air as shown and undergo total internal reflection on the fiber-cladding boundary?



A) 1.3°
B) 36°
C) 46°
D) 55°
E) 75°

$1.7 \times \sin\theta = 1.4 \cdot \sin 90°$
$\sin\theta_1 = \frac{1.4}{1.7} = 0.823$
$\cos\theta_1 = 0.567$
$n_{air} \sin\theta = n_{fib} \cdot \cos\theta_1$
$\sin\theta \approx 0.96$
$\theta = 74.66°$
$= 75°$
E

15. (6 points) A glass tube is at rest on a flat, level table. Two openings are exposed to the atmosphere, while a stopper closes the other opening. There is no air between the water and the stopper. The density of the oil in the left column is less than that of water. Is the pressure at point A greater than, less than, or equal to the pressure at point H? Points A and H are at the same height.



A) The pressure at point A is greater than the pressure at point H.
B) The pressure at point A is less than the pressure at point H.
C) The pressure at point A is equal to the pressure at point H.
D) There is not enough information to answer this question.

$P_H = 0$
$P_A = P_{Atm} = P_0$
A

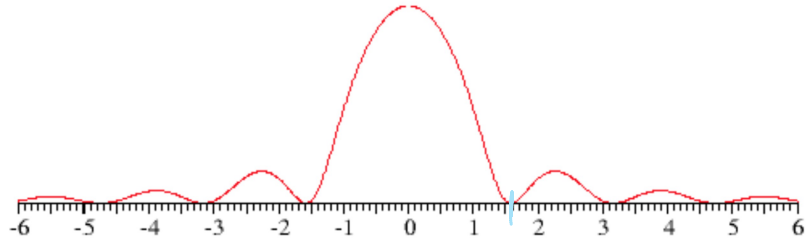
17. (6 points) Initially a toy boat with a rock on board floats in a small tub of water. You remove the rock from the boat and place it in the water, where it sinks to the bottom of the tub. Compared to the initial state with the rock on the boat, when the rock is placed in the water the water level ___.

A) rises
B) falls
C) stays the same
D) Need more information

B.
Previous: $V_{water} = \frac{m_{rock}}{\rho_{water}}$
Now: $V_{water} = V_{rock}$

Questions 23—24 below show the intensity graphs of the interference and/or diffraction patterns produced on a screen when either a single slit or a pair of slits is/are illuminated by a laser light of wavelength 633 nm. The distance of the screen from the slit(s) is 1.00 m. Match each pattern with its slit specification. (a=slit width, d=distance between slits)

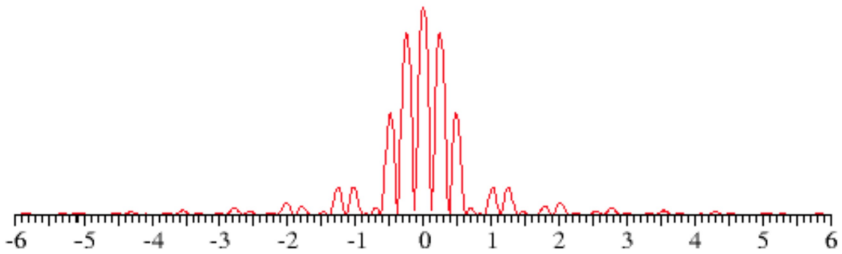
23. [5 pts]



a) Single slit, a=0.04 mm
b) Single slit, a=0.08 mm
c) Double slit, a=0.04 mm, d=0.12 mm
d) Double slit, a=0.04 mm, d=0.24 mm
e) Double slit, a=0.08 mm, d=0.24 mm

$D\sin\theta = m\lambda$ A
$D = 633n \div \left(\frac{1.6}{100}\right)$
$= 0.04mm$

24. [6 pts]



a) Single slit, a=0.04 mm
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c) Double slit, a=0.04 mm, d=0.12 mm
d) Double slit, a=0.04 mm, d=0.24 mm
e) Double slit, a=0.08 mm, d=0.24 mm

D

★★★★

Constants | Periodic Table

Planar waves from a monochromatic light source are normally incident on a circular obstacle, which casts a shadow on a screen positioned behind the obstacle.

Part A

What do the wave properties of light predict about how dark the center of the shadow is?

- The center of the pattern should be brighter than its surrounding.
- The center of the pattern should be darker than its surrounding.

Submit Previous Answers

Correct

Since all rays diffracting around the edge of the circular obstacle are equidistant from the center, all the waves should strike the center in phase, and therefore interfere constructively.

★★★★

Constants | Periodic Table

You are designing a thin transparent reflective coating for the front surface of a sheet of glass. The index of refraction of the glass is 1.52, and when it is in use the coated glass has air on both sides. Because the coating is expensive, you want to use a layer that has the minimum thickness possible, which you determine to be 104 nm.

Part A

What should the index of refraction of the coating be if it must cancel 540-nm light that hits the coated surface at normal incidence?

$n =$ 1.30

Submit Previous Answers

$\phi = \frac{4\pi nt}{\lambda} + \phi_{r_2} - \phi_{r_1}$

$\pi = \frac{4\pi nt}{\lambda}$

$n = \frac{\lambda}{4t} = 1.3$

Constants | Periodic Table

The pupil of the human eye can vary in diameter from 2.00 mm in bright light to 8.00 mm in dim light. The eye has a focal length of about 25 mm, and the visible spectrum extends from 390 nm (violet) to 750 nm (red). Note that the light-sensitive cells on the retina have radii ranging from 0.75 μm to 3.0 μm.

Part A

What smallest Airy disk radius is possible for the eye?

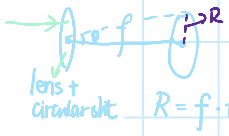
Express your answer with the appropriate units.

$y_{r,min}$ = 1.5×10^{-6} m

Submit | Previous Answers

✔ Correct

$\theta_r = 1.22 \cdot \frac{\lambda}{d}$



$R = f \cdot \tan\theta \approx f \cdot \theta$

$= 1.22 \frac{\lambda}{d} \cdot f$

$= 1.22 \cdot \frac{390\,nm}{8\,mm} \cdot 25\,mm$

$= 1.5 \times 10^{-6}\,m$

Part B

What largest Airy disk radius is possible for the eye?

Express your answer with the appropriate units.

$y_{r,max}$ = 1.14×10^{-5} m

Submit | Previous Answers

✔ Correct

$R = 1.22 \frac{\lambda}{d} f$

$= 25\,mm \times 1.22 \times \frac{750\,nm}{2\,mm}$

$= 1.14 \times 10^{-5}\,m$

Constants | Periodic Table

When a garden hose with an output diameter of 20 mm is directed straight upward, the stream of water rises to a height of 0.18 m. You then use your thumb to partially cover the output opening so that its diameter is reduced to 10 mm.

How high does the water rise now? Ignore drag and assume that the smaller opening you create with your thumb is circular.

Express your answer with the appropriate units.

h = 2.9 m

Submit | Previous Answers

Energy conservation: $\frac{1}{2}mv^2 = mgh$

$v_f = \sqrt{2gh} = 1.878\,m/s$

$A_1 v_1 = A_2 v_2$

$v_2 = \frac{A_1}{A_2} v_1 = 4 v_1 = 7.513\,m/s$

$h_2 = \frac{v_2^2}{2g} = 2.9\,m$