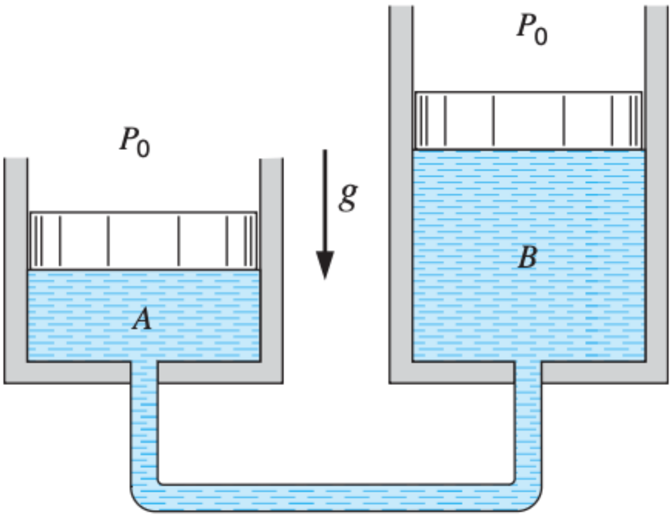
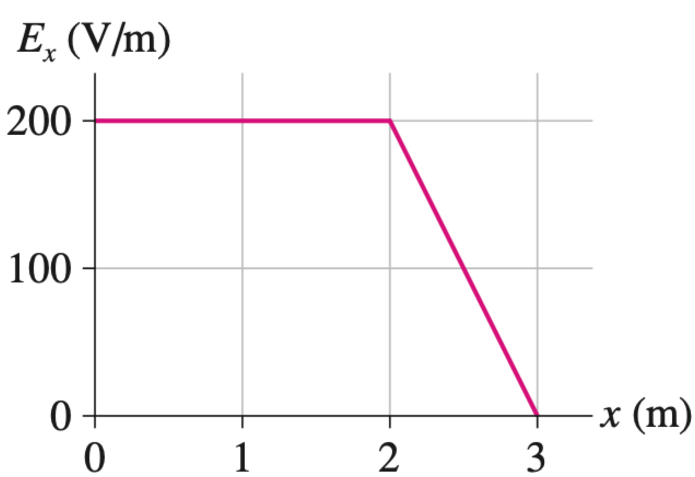
Question 1:



For Piston A:
$$P \cdot A_A = m_A g + P_0 \cdot A_A \Rightarrow P = P_0 + \frac{m_A g}{A_A}$$
For Piston B:
$$P \cdot A_B = m_B g + P_0 \cdot A_B \Rightarrow P = P_0 + \frac{m_B g}{A_B}$$
Equating the two expressions for P:
$$P_0 + \frac{m_A g}{A_A} = P_0 + \frac{m_B g}{A_B} \Rightarrow \frac{m_A}{A_A} = \frac{m_B}{A_B}$$
Solving for m_B:
$$m_B = m_A \cdot \frac{A_B}{A_A}$$
Substitute values:
$$m_A = 25\ kg. \quad A_A = 75\ cm^2. \quad A_B = 25\ cm^2$$
$$m_B = 25 \times \frac{25}{75} \approx 8.33\ kg.$$

Two piston/cylinder arrangements, A and B, have their gas chambers connected by a pipe, as shown in figure. The cross-sectional areas are $A_A = 75$ cm^2 and $A_B = 25$ cm^2, with the piston mass in A being $m_A = 25$ kg. Assume an outside pressure of 100 kPa and standard gravitation. Find the mass m_B so that none of the pistons have to rest on the bottom.

Question 2:



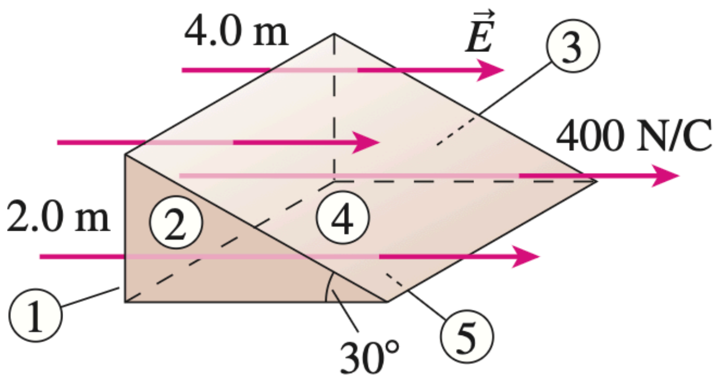
$$\Delta V = V(b) - V(a) = -\int_a^b E_x\, dx$$

Region 1: $0 \le x \le 2m$ (Constant $E_x = 200\ V/m$)
$$\Delta V_1 = -\int_0^2 200\, dx = -200 \cdot (2-0) = -400V$$
So, the potential at $x = 2m$ is:
$$V(2) = V(0) + \Delta V_1 = -50V - 400V = -450V$$

Region 2: $2 \le x \le 3m$ (Linearly Decreasing E_x)
$$E_x(x) = 200 - \frac{200}{1}(x-2) = 200(3-x)$$
$$\Delta V_2 = -\int_2^3 200(3-x)\, dx$$
Let $u = 3-x$, $du = -dx$
$$\Delta V_2 = -200\int_1^0 u(-du) = 200\int_0^1 u\, du = 200\left[\frac{u^2}{2}\right]_0^1 = 100V$$
So, the potential at $x = 3m$ is:
$$V(3) = V(2) + \Delta V_2 = -450V + 100V = -350V$$

The figure is a graph of E_x. The potential at the origin is $-50\ \mathrm{V}$. What is the potential at $x = 3.0\ \mathrm{m}$?

Question 3:



$\text{Area} = \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 4.0 \times 2.0 = 4.0\ m^2$

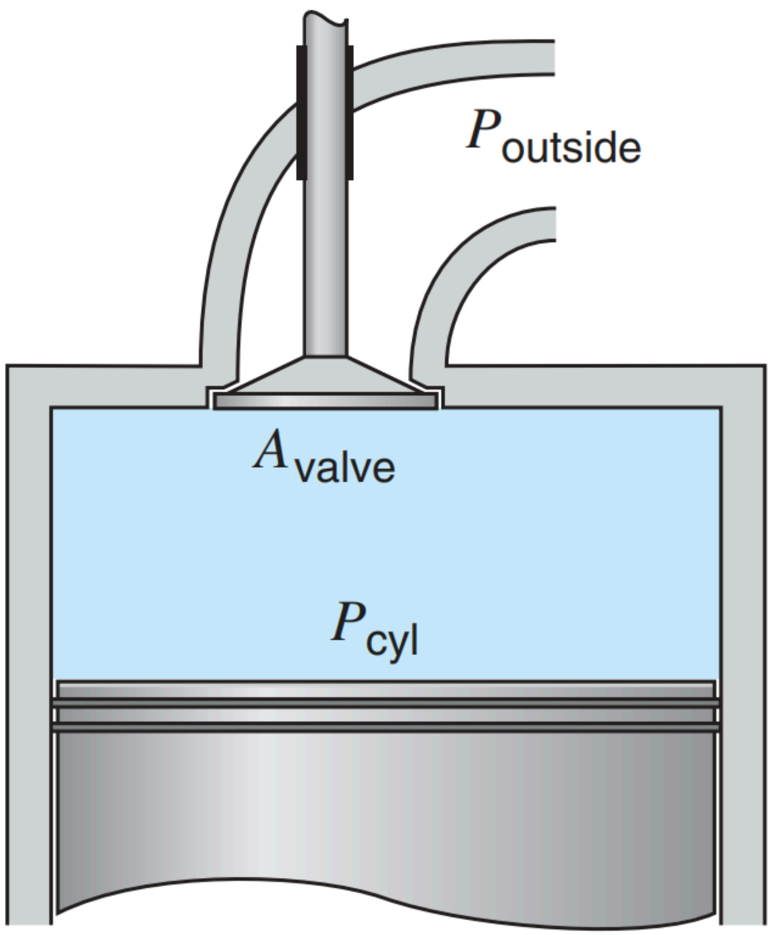
$\theta = 90° - 30° = 60°$

$\Phi_E = \vec{E} \cdot \vec{A} = E \cdot A \cdot \cos\theta$

$\Phi_E = 400 \times 4.0 \times \cos 60° = 400 \times 4.0 \times 0.5 = 800$ N\cdotpm²/C

Find the electric fluxe through surface 3. Find the electric fluxe through surface 3.

Question 4:

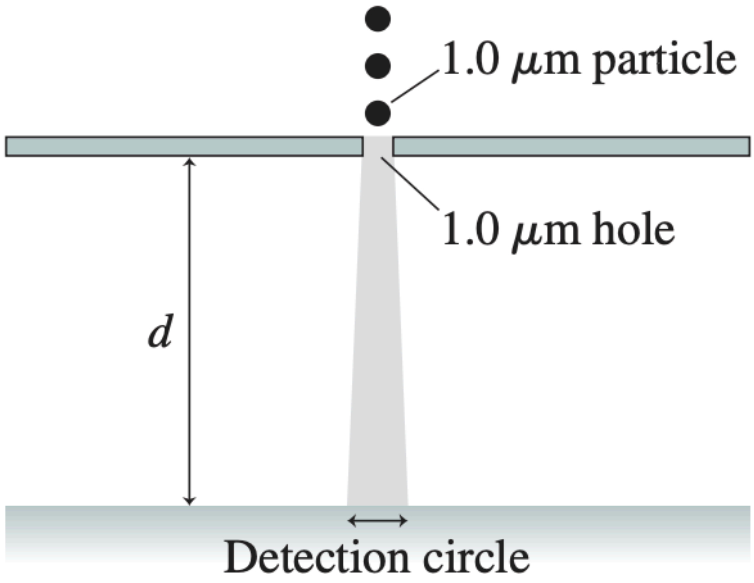


$\Delta P = P_{cyl} - P_{outside} = 735000\ Pa - 99000\ Pa = 636000\ Pa.$

$F = \Delta P \cdot A_{valve} = 636000\ Pa \times 0.0011\ m^2 = 699.6\ N$

A valve in the cylinder shown in figure has a cross-sectional area of $11\,\mathrm{cm}^2$ with a pressure of $735\,\mathrm{kPa}$ inside the cylinder and $99\,\mathrm{kPa}$ outside. How large a force is needed to open the valve?

Question 5:



$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$

$\Delta x_{initial} = 1.0\,\mu m = 1.0 \times 10^{-6} m$

$\Delta p \approx \frac{\hbar}{\Delta x_{initial}} = \frac{1.054 \times 10^{-34} J\backslash cdotps}{1.0 \times 10^{-6} m} = 1.054 \times 10^{-28} kg\backslash cdotpm/s$

$\Delta v = \frac{\Delta p}{m} = \frac{1.054 \times 10^{-28}}{1.0 \times 10^{-15}} = 1.054 \times 10^{-13} m/s$

$d = \frac{1}{2} g t^2 \Rightarrow t = \sqrt{\frac{2d}{g}}$

$\Delta x_{final} = \Delta v \cdot t = \frac{\hbar}{m \Delta x_{initial}} \cdot \sqrt{\frac{2d}{g}}$

Set $\Delta x_{final} = 0.1\,\mu m = 1.0 \times 10^{-7} m$

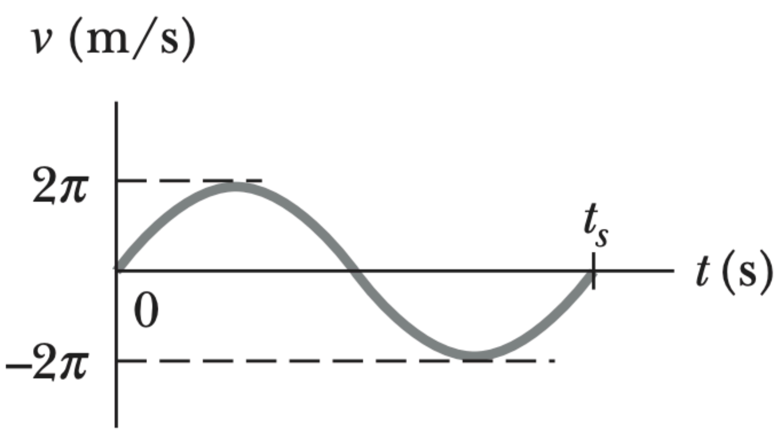
$\sqrt{\frac{2d}{9.81}} = \frac{1.0 \times 10^{-7}}{1.054 \times 10^{-13}} \approx 9.49 \times 10^{5}$

$\frac{2d}{9.81} = 9.01 \times 10^{11} \Rightarrow d = \frac{9.01 \times 10^{11} \cdot 9.81}{2}$

$\approx 4.42 \times 10^{12} m$

Figure shows 1.0-μm-diameter dust particles ($m = 1.0 \times 10^{-15}\ kg$) in a vacuum chamber. The dust particles are released from rest above a 1.0-μm-diameter hole, fall through the hole (there's just barely room for the particles to go through), and land on a detector at distance d below. Quantum effects would be noticeable if the detection-circle diameter increased by 10\% to $1.1\ \mu m$. At what distance d would the detector need to be placed to observe this increase in the diameter?

Question 6:



$E_{total} = \frac{1}{2} k A^2$

$E_{max} = \frac{1}{2} \times 200 \times (0.20)^2 = 4.0 J$

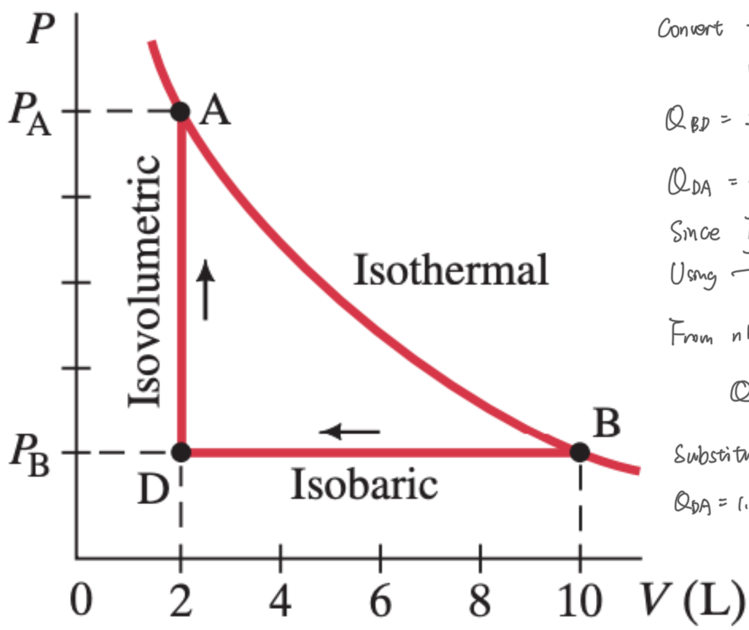
$\omega = \frac{V_{max}}{A} = \frac{2\pi}{0.20} = 10\pi\ rad/s$

$\omega = \sqrt{\frac{k}{m}} \Rightarrow m = \frac{k}{\omega^2} = \frac{200}{(10\pi)^2}$

$K_{max} = \frac{1}{2} m v_{max}^2 = \frac{1}{2} \times \frac{200}{(10\pi)^2} \times (2\pi)^2 = 4.0 J$

A simple harmonic oscillator consists of a block attached to a spring with $k = 200\,\mathrm{N/m}$. The block slides on a frictionless surface, with equilibrium point $x = 0$ and amplitude $0.20\,\mathrm{m}$. A graph of the block's velocity v as a function of time t is shown in figure. The horizontal scale is set by $t_s = 0.20\,\mathrm{s}$. What is its maximum kinetic energy?

Question 7:



$W_{BD} = P\Delta V = (2.0\,\text{atm})\cdot(2.0L - 10.0L) = -8.0$ L\cdotpatm

Convert to Joules (1L\cdotpatm = 101.325)

$W_{BD} = -8.0 \times 101.325 = -810.6J$

$Q_{BD} = \frac{5}{2} W_{BD} = \frac{5}{2} \times (-810.6) = -2026.5J$ (heat flows out)

$Q_{DA} = \frac{3}{2}\cdot nR\Delta T$

Since $T_A = T_B$, the temperature change $\Delta T = T_B - T_D$.

Using $\frac{T_D}{T_B} = \frac{V_D}{V_B} = \frac{2}{10}$. $\Delta T = T_B - 0.2T_B = 0.8T_B$

From $nR = \frac{P_B V_B}{T_B}$

$Q_{DA} = \frac{3}{2}\cdot\frac{P_B V_B}{T_B}\cdot 0.8T_B = 1.2\cdot P_B V_B$

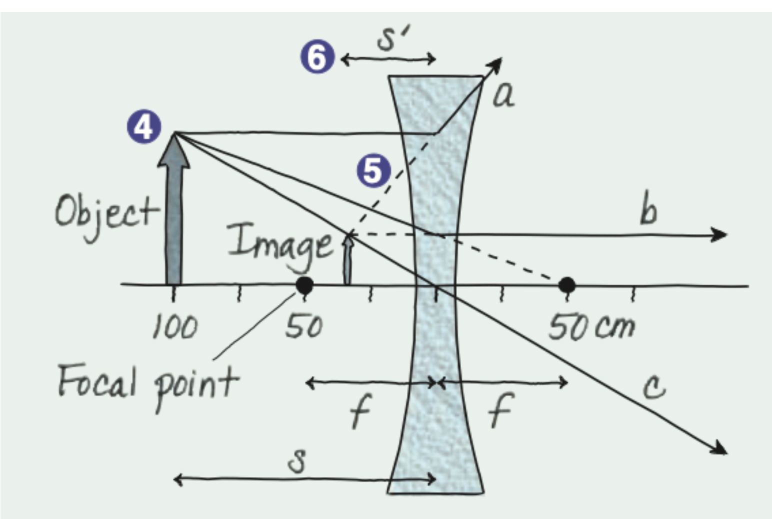
Substitute $P_B = 2.0$ atm. $V_B = 10.0L$

$Q_{DA} = 1.2 \times (2.0 \times 10.0)$ L\cdotpatm = 24.0 L\cdotpatm = $24.0 \times 101.325 = 2431.8J$

$Q_{total} = Q_{BD} + Q_{DA} = -2026.5J + 2431.8J = 405.3J$

An ideal gas is slowly compressed at a constant pressure of $2.0\,\mathrm{atm}$ from $10.0\,\mathrm{L}$ to $2.0\,\mathrm{L}$. This process is represented in figure as the path B to D. (In this process, some heat flows out of the gas and the temperature drops.) Heat is then added to the gas, holding the volume constant, and the pressure and temperature are allowed to rise (line DA) until the temperature reaches its original value $(T_A = T_B)$. In the process BDA, calculate the total heat flow into the gas.

Question 8:



$f = -50\,cm$ $d_o = 100\,cm$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$-\frac{1}{50} = \frac{1}{100} + \frac{1}{d_i}$

$\frac{1}{d_i} = -\frac{1}{50} - \frac{1}{100} = -\frac{3}{100}$

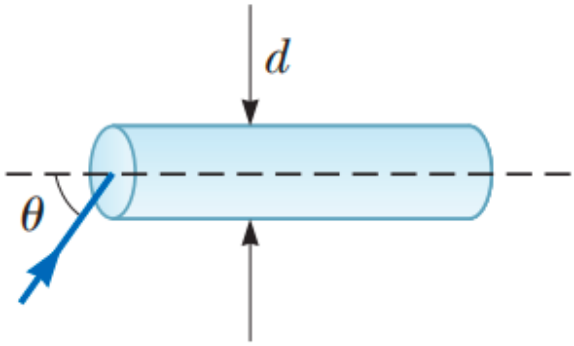
$d_i \approx -33.33\,cm$

$m = -\frac{d_i}{d_o}$

$m = -\left(\frac{-33.33}{100}\right) = 0.333$

A diverging lens with a focal length of 50 cm is placed 100 cm from a flower. What is the magnification?

Question 9:



$\sin\theta_c = \frac{n_{air}}{n} = \frac{1.00}{1.36} \approx 0.7353$

$\theta_c = \sin^{-1}(0.7353) \approx 47.3°$

$n_{air}\sin\theta = n\sin\phi$

$\phi = 90° - \theta_c = 42.7°$

$\sin\theta = n\sin\phi = 1.36\sin 42.7° \approx 0.922$

$\theta = \sin^{-1}(0.922) \approx 67.2°$

Assume a transparent rod of diameter $d = 2.00\ \mu\text{m}$ has an index of refraction of 1.36. Determine the maximum angle θ for which the light rays incident on the end of the rod in figure are subject to total internal reflection along the walls of the rod.

C .

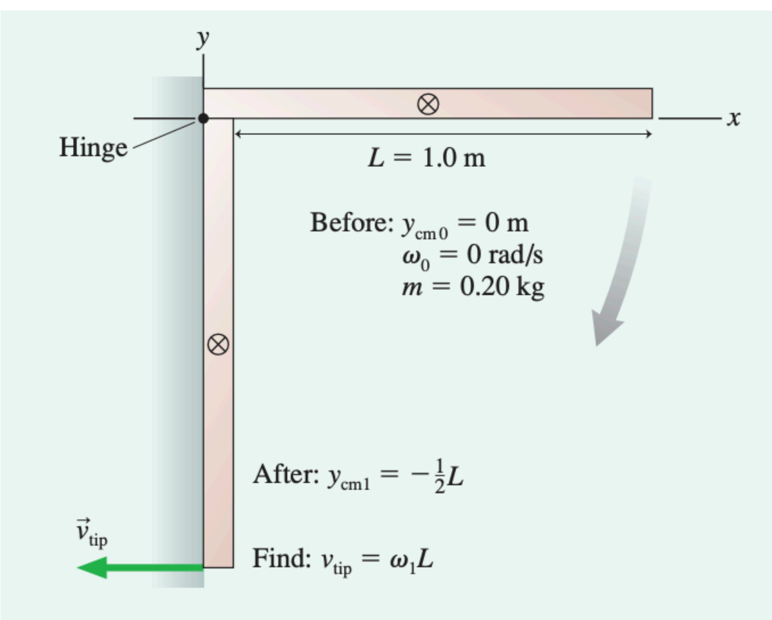
A. 72.2°

B. 65.4°

C. 67.2° ✓

D. 60.0°

Question 10:



$\Delta y = \frac{L}{2}$

$\Delta PE = mg\Delta y = mg\frac{L}{2}$

$KE_{rot} = \frac{1}{2}Iw^2 = \frac{1}{2}\left(\frac{1}{3}mL^2\right)w^2 = \frac{1}{6}mL^2w^2$

$mg\frac{L}{2} = \frac{1}{6}mL^2w^2$

$g\frac{L}{2} = \frac{1}{6}L^2w^2 \Rightarrow w = \sqrt{\frac{3g}{L}}$

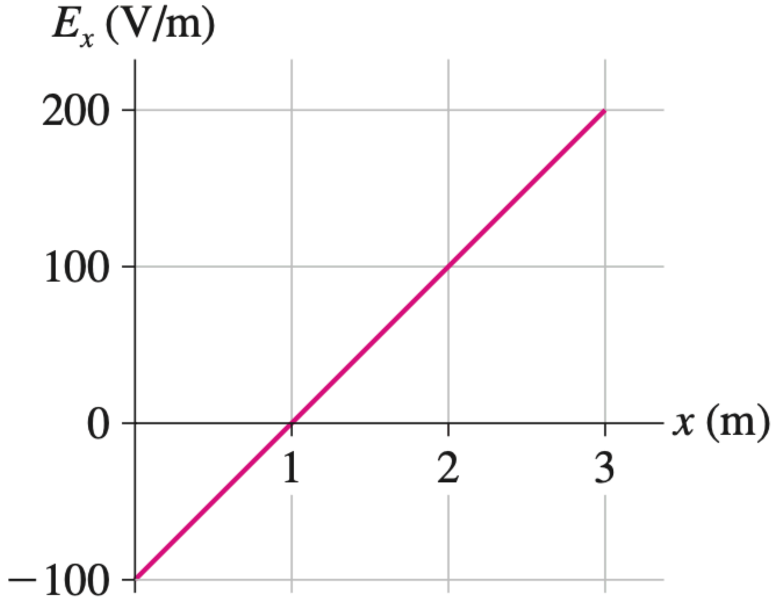
$V_{tip} = wL = L\sqrt{\frac{3g}{L}} = \sqrt{3gL}$

$= \sqrt{3\times9.8\times1.0}$

$\approx 5.42\ m/s$

A $1.0\ \text{m}$-long, $200\ \text{g}$ rod is hinged at one end and connected to a wall. It is held out horizontally, then released. What is the speed of the tip of the rod as it hits the wall?

Question 11:



$\Delta V = -\int_{x_i}^{x_f} E_x \, dx$

$E_x(x) = \text{slope} \cdot (x - x_0)$

$\text{Slope} = \dfrac{200\ V/m - 0\ V/m}{3.0\ m - 1.0\ m} = 100\ V/m^2$

$E_x(x) = 100\,(x - 1.0)\ V/m.$ for $1.0\ m \leq x \leq 3.0\ m$

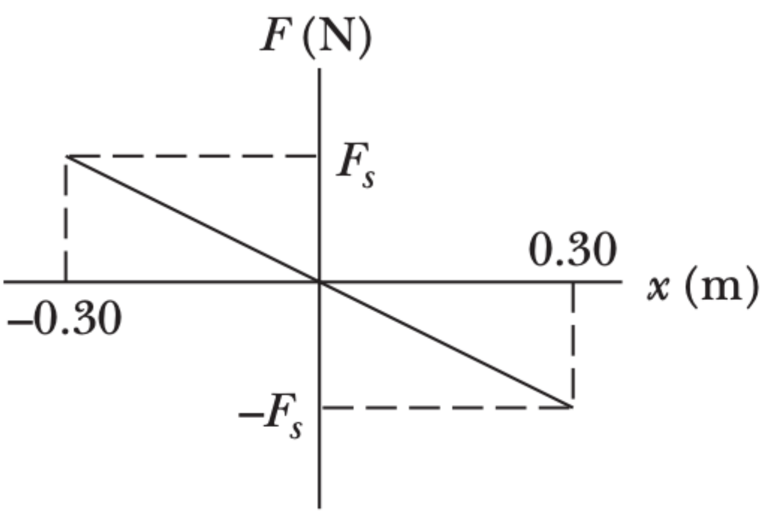
$\Delta V = -\int_{1.0}^{3.0} 100\,(x - 1.0)\, dx$

Let $u = x - 1.0$, $du = dx$

$\Delta V = -100 \int_0^2 u\, du = -100 \left[\dfrac{u^2}{2}\right]_0^2 = -200\ V$

The figure is a graph of E_x. What is the potential difference between $x_i = 1.0\ \mathrm{m}$ and $x_f = 3.0\ \mathrm{m}$?

Question 12:



$k = \dfrac{F_s}{A} = \dfrac{75.0\ N}{0.30\ m} = 250\ N/m$

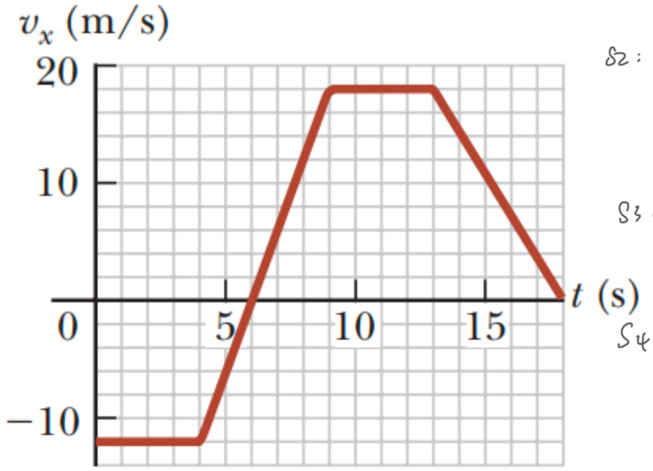
$K_{max} = \dfrac{1}{2} k A^2$

$= \dfrac{1}{2} \times 250 \times (0.30)^2$

$= 11.25\ J$

A simple harmonic oscillator consists of a $0.50\ kg$ block attached to a spring. The block slides back and forth along a straight line on a frictionless surface with equilibrium point $x = 0$. At $t = 0$ the block is at $x = 0$ and moving in the positive x direction. A graph of the magnitude of the net force $\vec{F}$ on the block as a function of its position is shown in figure. The vertical scale is set by $F_s = 75.0\ N$. What is the maximum kinetic energy?

Question 13:



S1: t=0~5s. V=-10m/s

$d_1 = |v| \cdot \Delta t = 10m/s \times 5s = 50m$

S2: t=5~10s. V: Linear from -10m/s to 20m/s

$V_{avg} = \frac{-10+20}{2} = 5m/s$

$d_2 = V_{avg} \cdot \Delta t = 5m/s \times 5s = 25m$

S3: t=10~15s V: constant V=20m/s

$d_3 = v \cdot \Delta t = 20m/s \times 5s = 100m$

S4: t=15~18s. V: Linear from 20m/s to 10m/s

$V_{avg} = \frac{20+0}{2} = 10m/s$

$d_4 = V_{avg} \cdot \Delta t = 10m/s \times 3s = 30m.$

$d_{total} = d_1 + d_2 + d_3 + d_4 = 205m.$

An object is at $x = 0$ at $t = 0$ and moves along the x axis according to the velocity--time graph in figure. Through what total distance has the object moved between $t = 0$ and $t = 18.0$ s?

A. 272m

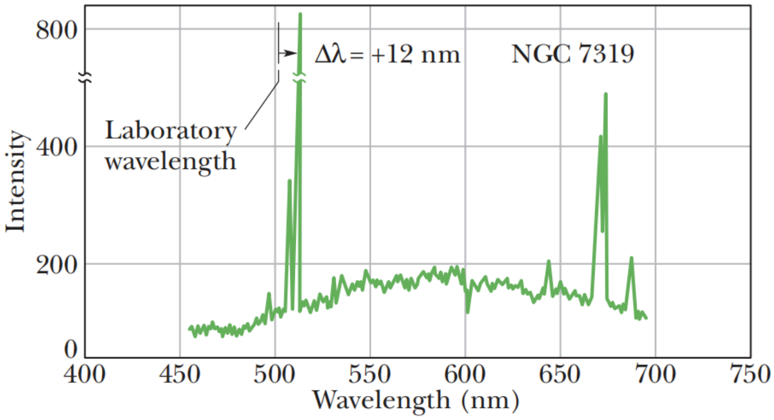
C.

B. 136m

C. 204m

D. 182m

Question 14:



$\frac{\lambda-\lambda_0}{\lambda_0} = \frac{525\times10^{-9}-513\times10^{-9}}{513\times10^{-9}} = \frac{12}{513} \approx 0.0234$

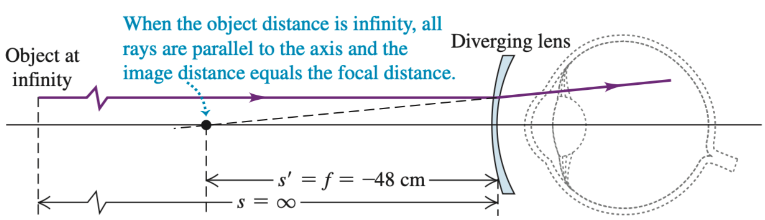
$v = c \times \frac{\lambda-\lambda_0}{\lambda_0}$

$c = 3\times10^{8}\, m/s$

get $v = (3\times10^{8})\times\frac{12}{513}\, m/s \approx 7\times10^{6}\, m/s$

Figure is a graph of intensity versus wavelength for light reaching Earth from galaxy NGC 7319, which is about 3×10^8 light-years away. The most intense light is emitted by the oxygen in NGC 7319. In a laboratory that emission is at wavelength $\lambda = 513\,\mathrm{nm}$, but in the light from NGC 7319 it has been shifted to $525\,\mathrm{nm}$ due to the Doppler effect (all the emissions from NGC 7319 have been shifted). What is the radial speed of NGC 7319 relative to Earth?

Question 15:

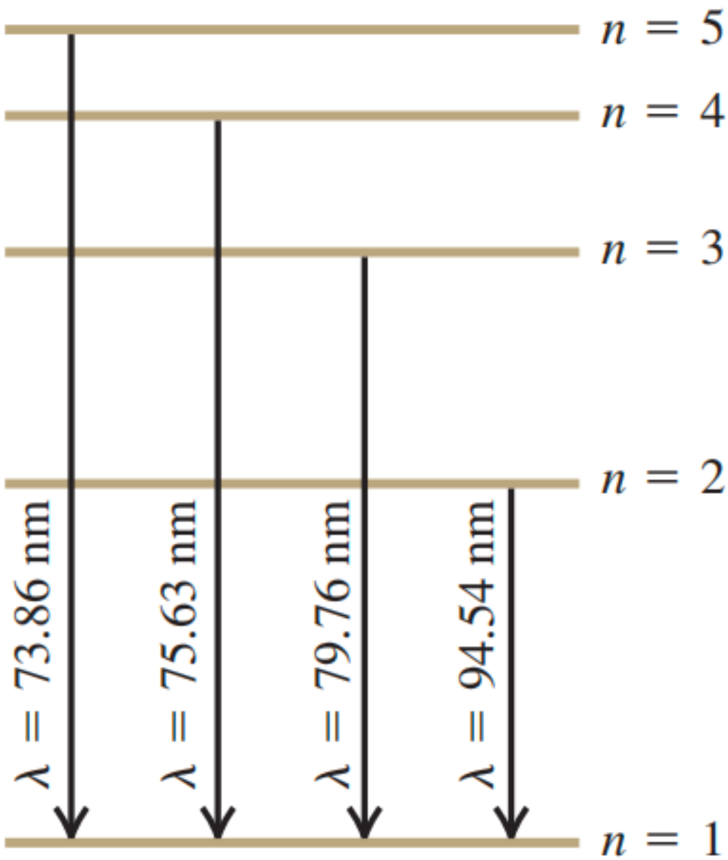


The far point of a certain myopic eye is 50 cm in front of the eye. Assume that the lens is worn 2 cm in front of the eye. Find the focal length of the eyeglass lens that will permit the wearer to see clearly an object at infinity.

$s' = -(50cm - 2cm) = -48cm$

$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} = \frac{1}{\infty} + \frac{1}{-48cm} \Rightarrow f = -48cm$

Question 16:



$E_1 = -17.50\ eV$

$E_n = \frac{E_1}{n^2}$

$E_2 = \frac{-17.50}{4} = -4.375 eV$

$E_4 = \frac{-17.50}{16} = -1.09375 eV.$

$\Delta E = E_4 - E_2 = -1.09375 - (-4.375) = 3.28125 eV$

$\lambda = \frac{hc}{\Delta E} = \frac{1240 eV \backslash cdotp nm}{3.28125\ eV} \approx 378 nm$

In a set of experiments on a hypothetical one-electron atom, you measure the wavelengths of the photons emitted from transitions ending in the ground state $n = 1$, as shown in the energy-level diagram in figure. You also observe that it takes $17.50\ \mathrm{eV}$ to ionize this atom. If an electron made a transition from the $n = 4$ to the $n = 2$ level, what wavelength of light would it emit?

A. $323\ \mathrm{nm}$

B. $456\ \mathrm{nm}$

C. $423\ \mathrm{nm}$

D. $378\ \mathrm{nm}$

Question 17:

The alpenhorn (figure) was once used to send signals from one Alpine village to another. Since lower frequency sounds are less susceptible to intensity loss, long horns were used to create deep sounds. When played as a musical instrument, the alpenhorn must be blown in such a way that only one of the overtones is resonating. The most popular alpenhorn is about $3.4\,\mathrm{m}$ long, and it is called the F\# (or G\flat) horn.Model as a tube open at both ends. What is the fundamental frequency of this horn?

$$f_1 = \frac{v}{2L} = \frac{343\,m/s}{2\times 3.4\,m} \approx 50.44\,Hz$$

Question 18:

A heat engine's high temperature T_H could be ambient temperature, because liquid nitrogen at $77\,\mathrm{K}$ could be T_L and is cheap.The Carnot engine made use of heat transferred from air at room temperature ($293\,\mathrm{K}$) to the liquid nitrogen fuel (figure). What would be the efficiency of a Carnot engine?

$$\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{77K}{293K} \approx 0.7372$$

$$\eta = 73.7\%$$