

Name

KEY

Student ID

Check your (CRN) section number:

14291	8:00 - 8:50
14288	9:05 - 9:55
14296	10:10 - 11:00
14295	11:15 - 12:05

Students may also use their own two sided 8.5" x 11" formula sheet.

Chapter 15

$$v = f\lambda$$

$$\frac{\partial y(x,t)}{\partial t} = \mp v \frac{\partial y(x,t)}{\partial x}$$

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

$$k = \frac{2\pi}{\lambda}$$

$$v = \sqrt{\frac{F}{\mu}}$$

$$y(x,t) = A_{sw} \sin(kx) \cos(\omega t)$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$\frac{\partial^2 y(x,t)}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y(x,t)}{\partial t^2}$$

$$\text{Power} = F_y(x,t)v_y(x,t)$$

$$P_{av} = \frac{1}{2} \sqrt{\mu F} \omega^2 A^2$$

Chapter 16

$$p(x,t) = -B \frac{\partial y(x,t)}{\partial x}$$

$$p_{max} = BkA$$

$$v = \sqrt{\frac{B}{\rho}}$$

$$v = \sqrt{\frac{\gamma RT}{M}}$$

$$T_{kelvin} = T_C + 273.15$$

$$v = \sqrt{\frac{Y}{\rho}}$$

$$I = \langle p(x,t)v_y(x,t) \rangle_t$$

$$I = \frac{1}{2} \sqrt{\rho B} \omega^2 A^2$$

$$\beta = (10dB) \log \frac{I}{I_0}$$

$$I_0 = 10^{-12} \frac{W}{m^2}$$

$$f_{beat} = f_a - f_b$$

$$f_L = \frac{v+v_L}{v+v_S} f_S$$

Chapter 21

$$F = k \frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_2|}{r^2}$$

$$p = dq$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$k = 8.988 \times 10^9 \frac{Nm^2}{C^2}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$$

$$\vec{\tau} = \vec{p} \times \vec{E}$$

Chapter 22

$$\Phi_E \equiv \int \vec{E} \cdot d\vec{A} \quad \oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$

Chapter 23

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r} \quad -\Delta V = V_a - V_b = \int_a^b \vec{E} \cdot d\vec{l} \quad \vec{E} = -\left(\hat{i} \frac{\partial V}{\partial x} + \hat{j} \frac{\partial V}{\partial y} + \hat{k} \frac{\partial V}{\partial z}\right)$$

1. A transverse wave traveling on a string is described by the expression  $y(x,t) = 3.2 \text{ mm} \sin [2 \pi ( 1.3 x / \text{m} + 10 t / \text{s} ) ]$ , where  $\text{m}=\text{meters}$ ,  $\text{mm}=\text{millimeters}$ , and  $\text{s}=\text{seconds}$ . What is the frequency,  $f$ , of this wave?

A	20 $\pi$ Hz	F	1.6 Hz
B	1.3 Hz	G	2.42 Hz
<b>C</b>	10 Hz	H	20 Hz
D	0.1 Hz	I	0.314 Hz
E	12 Hz	J	314 Hz

$$2\pi \frac{10 t}{s} = 2\pi f t \Rightarrow f = 10 \frac{1}{s} = 10 \text{ Hz}$$

2. For the wave in problem 1, what is the period,  $T$ , of the wave?

<b>A</b>	0.1 s	F	0.159 s
B	10 s	G	7.69 s
C	1.3 s	H	76.9 s
D	0.769 s	I	769 s
E	62.8 s	J	1 s

$$T = \frac{1}{f} = \frac{1}{10} \text{ s} = 0.1 \text{ s}$$

3. For the wave in problem 1, what is the wavelength,  $\lambda$ , of the wave?

A	1.3 m	F	3.2 mm
B	2.42 m	G	0.13 m
C	13 m	H	13 mm
<b>D</b>	0.769 m	I	2.6 m
E	7.69 m	J	8.17 m

$$\frac{2\pi}{\lambda} x = 2\pi \frac{1.3 x}{\text{m}} \Rightarrow \lambda = \frac{\text{m}}{1.3} \approx 0.769 \text{ m}$$

4. For the wave in problem 1, what is the speed,  $v$ , of the wave?

<b>A</b>	7.69 m/s	F	0.769 m/s
B	3.14 m/s	G	344 m/s
C	1.3 m/s	H	1 m/s
D	10 m/s	I	62.8 m/s
E	13 m/s	J	20 m/s

$$v = \lambda f = \left(\frac{\text{m}}{1.3}\right) \left(10 \frac{1}{\text{s}}\right) \approx 7.692 \text{ m/s}$$

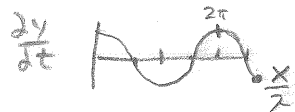
5. For the wave in problem 1, what is the direction the wave is traveling?

<b>A</b>	- x direction	F	- z direction
B	+ x direction	G	it's not moving
C	up	H	cannot be determined
D	+ y direction	I	- y direction
E	+ z direction	J	down

The wave is of the form  
 $y(x,t) = f(x + vt)$   
 so it's traveling to the  
 - x direction

6. For the wave in problem 1, find the transverse velocity of the wave at time  $t=3s$  and position  $x=1m$ .

$$y = A \sin(kx + \omega t) \quad \frac{\partial y}{\partial t} = \omega A \cos(kx + \omega t)$$



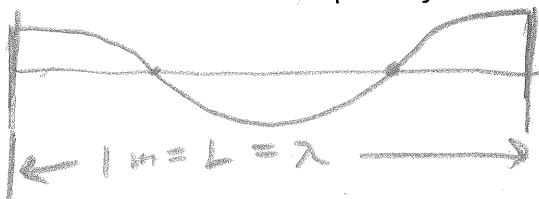
$$\frac{\partial y}{\partial t}(1m, 3s) = (2\pi \frac{10}{s})(3.2mm) \cos(2\pi \cdot 1.3 + 2\pi \cdot 30)$$

$$\approx -6.21315 \times 10^{-1} \text{ mm/s}$$

$$\approx -62.1 \text{ mm/s}$$

A	13.2 mm/s	F	19.4 mm/s
B	10.2 mm/s	G	-10.2 mm/s
C	65.8 mm/s	<b>H</b>	-62.1 mm/s
D	31.4 mm/s	I	-19.4 mm/s
E	0	J	3.14 mm/s

7. A pipe of length  $L=1m$  is open at both ends. Use  $v=344 \text{ m/s}$  for the speed of sound. Find the frequency of the first overtone (second harmonic).



$$f = \frac{v}{\lambda} = \frac{v}{L} = \frac{344 \text{ m/s}}{1 \text{ m}}$$

$$= 344 \text{ Hz}$$

A	34 Hz	F	688 Hz
B	3.44 Hz	G	229 Hz
C	2160 Hz	H	516 Hz
D	1080 Hz	<b>I</b>	344 Hz
E	172 Hz	J	444 Hz

8. A string of length 2 m and mass 0.01 kg is fixed at both ends. If the first harmonic resonant frequency is 30 Hz, then the tension in the string is:



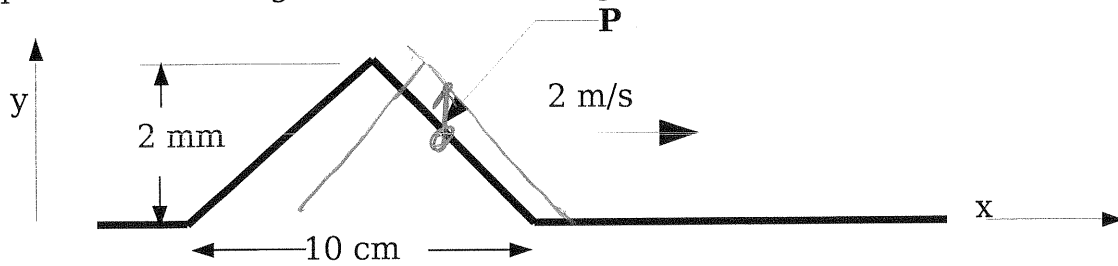
$$\Rightarrow f\lambda = \sqrt{\frac{FL}{M}} \Rightarrow f(2L) = \sqrt{\frac{FL}{M}}$$

$$\Rightarrow \sqrt{F} = \sqrt{\frac{M}{L}} f(2L) = \sqrt{ML} \cdot 2f$$

$$\Rightarrow F = ML \cdot 4f^2 = (0.01 \text{ kg})(2 \text{ m}) 4 \left(30 \frac{1}{s}\right)^2 = 72 \text{ N}$$

A	36 N	F	30 N
B	18 N	G	0.6 N
C	144 N	H	100 N
<b>D</b>	72 N	I	12 N
E	50 N	J	24 N

9. The triangular wave pulse, 2 mm high and 10 cm wide with a peak 5 cm from the start of the pulse, illustrated below, moves on a string at a speed of 2 m/s to the right. What is the transverse velocity of the string,  $v_y$ , at the point on the string, at the forward edge of the triangle, labeled as **P**?



$$v_y = - \frac{\Delta y}{\Delta x} v = - \left( \frac{-2 \text{ mm}}{5 \text{ cm}} \right) 2 \text{ m/s} \left( \frac{10^{-3} \text{ m}}{\text{mm}} \right) \left( \frac{\text{cm}}{10^{-2} \text{ m}} \right)$$

$$= \frac{4}{5} 10^{-1} \text{ m/s} = \frac{4}{50} \text{ m/s} = 0.08 \text{ m/s}$$

A	20 m/s	F	25 m/s
B	10 m/s	G	2.5 m/s
3	<b>C</b> 0.08 m/s	H	-0.085 m/s
D	0.04 m/s	I	-12.5 m/s
E	12.5 m/s	J	-0.04 m/s

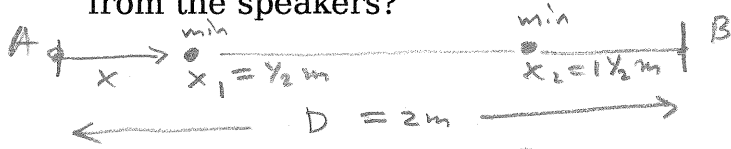
10. A spherical sound wave with 20 Watt of power is emitted from a point. What is the intensity of the sound, in dB, that will be heard at a distance of 10 meters from this source?

$$B = 10 \text{ dB} \log \left( \frac{\text{Power}}{4\pi r^2 I_0} \right) = 10 \text{ dB} \log \left( \frac{20 \text{ W}}{4\pi (10 \text{ m})^2 \cdot 10^{-12} \frac{\text{W}}{\text{m}^2}} \right)$$

$$= 10 \text{ dB} \log \left( \frac{5}{\pi} 10^{10} \right) \approx 102.0182 \text{ dB}$$

A	-10 dB	F	48 dB
B	13 dB	<b>G</b>	102 dB
C	20 dB	H	113 dB
D	33 dB	I	123 dB
E	41 dB	J	200 dB

11. Two sound speakers are driven in phase, by a single tone, and are separated by  $D=2$  meters. An observer walking between the two speakers notices that the sound she hears becomes louder and softer as she moves. If she hears only two minimums, which are when she is between the speakers at  $\frac{1}{2}$  meter ( $\frac{1}{4} D$ ) from either speaker. What is the wavelength of the sound from the speakers?



path diff  $\equiv d = x - (D - x)$   
 $= 2x - D$

①  $2x_2 - D = n \cdot \frac{\lambda}{2}$     *n odd*

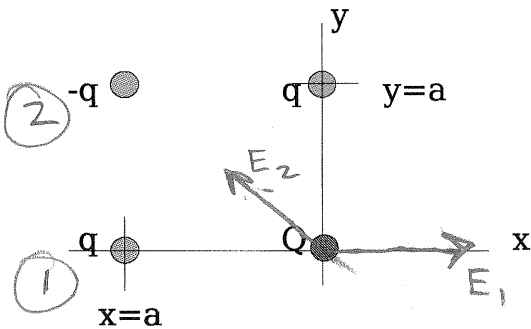
②  $2x_1 - D = (n-2) \cdot \frac{\lambda}{2} = n \cdot \frac{\lambda}{2} - \lambda$

① - ②  $\Rightarrow 2x_2 - 2x_1 = \lambda$

$\Rightarrow \lambda = 2(x_2 - x_1) = 2(\frac{1}{2}\text{ m} - \frac{1}{2}\text{ m})$   
 $= 2\text{ m}$

<input checked="" type="radio"/> A	2 m	F	$\frac{1}{2}$ m
<input type="radio"/> B	4 m	G	$\frac{1}{4}$ m
<input type="radio"/> C	10 m	H	3.14 m
<input type="radio"/> D	344 m	I	8 m
<input type="radio"/> E	172 m	J	16 m

12. Three charges:  $q$  at  $(-a, 0)$ ,  $q$  at  $(0, a)$ , and  $-q$  at  $(-a, a)$  are shown in the figure act on a fourth charge,  $Q$ , that is at the origin.  $Q$  and  $q$  are both positive. So  $-q < 0$ . Find the  $x$  component of the force on the charge at the origin. Use  $k = 1/(4\pi\epsilon_0)$ .



$E_x = E_1 - E_2 \frac{1}{\sqrt{2}} = E_1 - E_2 \cos 45^\circ$

$E_1 = \frac{kqQ}{a^2}$

$E_2 = \frac{k \frac{qQ}{(\sqrt{2}a)^2}}$

$= \frac{1}{2} k \frac{qQ}{a^2}$


$\Rightarrow E_x = \frac{kqQ}{a^2} - \frac{1}{2} k \frac{qQ}{a^2} \frac{1}{\sqrt{2}}$

$= \left(1 - \frac{1}{2\sqrt{2}}\right) k \frac{qQ}{a^2}$

$\approx 0.6464466 k \frac{qQ}{a^2}$

A	$3.83 k q Q / a^2$	F	$1.71 k q Q / a^2$
B	$1.83 k q Q / a^2$	G	$0.414 k q Q / a^2$
<input checked="" type="radio"/> C	$0.646 k q Q / a^2$	H	$-0.414 k q Q / a^2$
D	$-0.65 k q Q / a^2$	I	$-0.293 k q Q / a^2$
E	$0.5 k q Q / a^2$	J	$0.293 k q Q / a^2$

13. Two tuning forks are ringing. One of the tuning forks rings with a frequency of 256 Hz and the other is a little less. If the beat frequency for the two forks is measured to be 2 Hz, what is the frequency of the fork with the lower frequency?

  
 $f_1 = 256 \text{ Hz}$        $f_2 = ?$

$$f_{\text{beat}} = f_1 - f_2$$

$$\Rightarrow f_2 = f_1 - f_{\text{beat}}$$

$$= 256 \text{ Hz} - 2 \text{ Hz}$$

$$= 254 \text{ Hz}$$

6

A	249 Hz	<b>F</b>	254 Hz
B	250 Hz	G	255 Hz
C	251 Hz	H	256 Hz
D	252 Hz	I	257 Hz
E	253 Hz	J	258 Hz

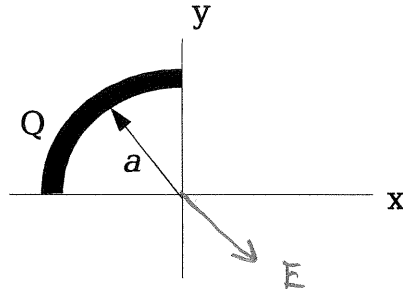
14. A spherical sound wave is emitted by a point source. How many decibels does the sound intensity level change when you move from 1/2 meter from the source to 5 meters from the source?

$$\begin{aligned}
 \Delta \beta &= \beta_2 - \beta_1 = 10 \text{ dB} \log \left( \frac{\text{Power}}{4\pi r_2^2 I_0} \right) - 10 \text{ dB} \log \left( \frac{\text{Power}}{4\pi r_1^2 I_0} \right) \\
 &= 10 \text{ dB} \log \left( \frac{r_1^2}{r_2^2} \right) = 10 \text{ dB} \log \left( \frac{(1/2)^2}{(5)^2} \right) \\
 &= 10 \text{ dB} \log \left( \frac{1}{10^2} \right) = 10 \text{ dB} (-2) \\
 &= -20 \text{ dB}
 \end{aligned}$$

2

A	-40 dB	F	40 dB
<b>B</b>	-20 dB	G	100 dB
C	0 dB	H	200 dB
D	10 dB	I	400 dB
E	20 dB	J	800 dB

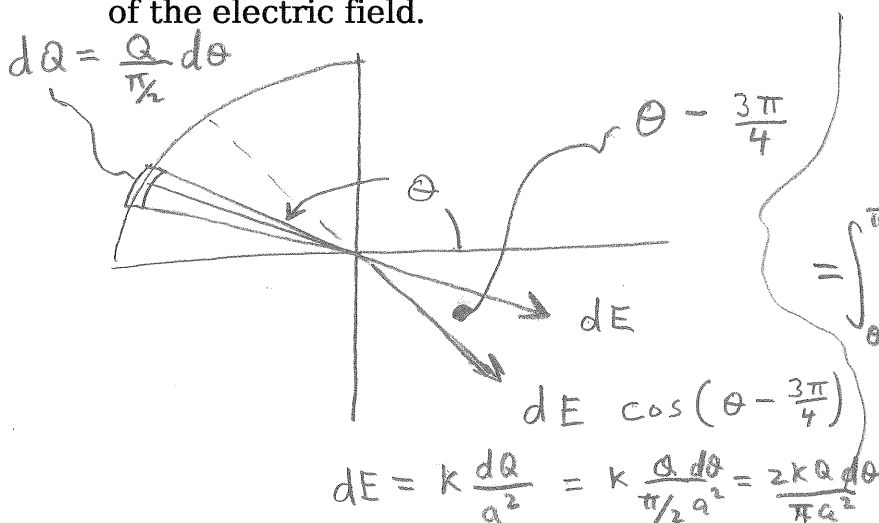
15. Consider the circular arc with total charge  $Q$  uniformly distributed over the arc.  $Q$  is greater than zero. The radius of the arc is  $a$ , with the angle of arc swing being  $90^\circ$ . The arc is in the quadrant shown in the figure below. The center of the arc is at the origin. Find the direction of the electric field at the origin.



cw = clockwise    ccw = counter-clockwise

A	x direction	F	45° cw from - x
B	y direction	G	none E=0
C	45° ccw from x	H	55° ccw from x
4	<b>D</b> 45° cw from x	I	90° ccw from x
E	45° ccw from - x	J	55° cw from x

16. From problem 15, in terms of  $k=1/(4 \pi \epsilon_0)$ ,  $Q$ , and  $a$ , find the magnitude of the electric field.



$$dQ = \frac{Q}{\pi/2}$$

$$E = \int_{\theta=\pi/2}^{\pi} (dE) \cos(\theta - \frac{3\pi}{4})$$

$$= \int_{\theta=\pi/2}^{\pi} \frac{2kQ}{\pi a^2} \cos(\theta - \frac{3\pi}{4}) d\theta$$

$$= \frac{2kQ}{\pi a^2} \left[ \sin(\theta - \frac{3\pi}{4}) \right]_{\theta=\pi/2}^{\pi}$$

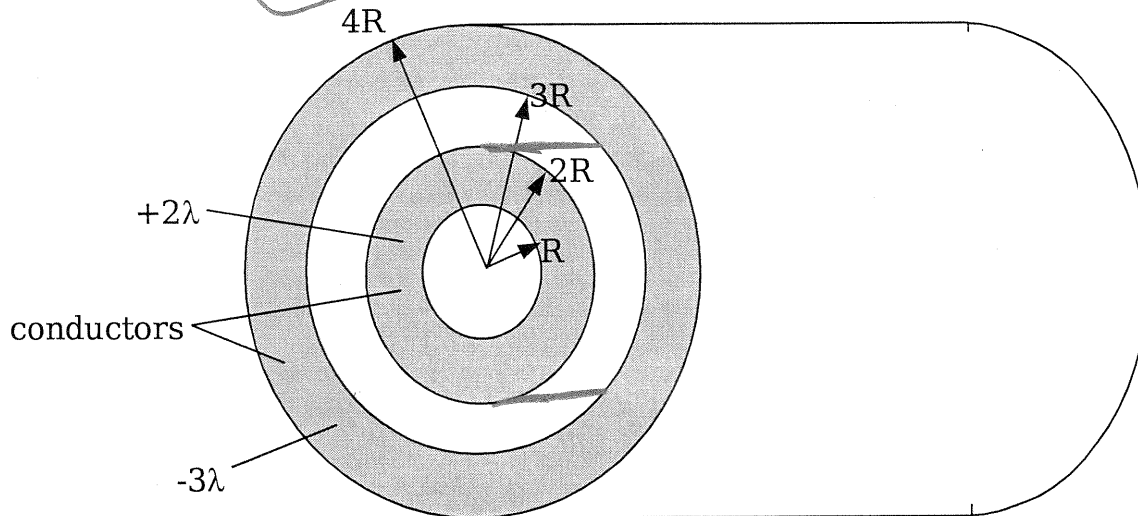
$$= \frac{2kQ}{\pi a^2} \left[ \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}} \right]$$

$$= \frac{4}{\sqrt{2}} \frac{kQ}{\pi a^2} = 2\sqrt{2} \frac{kQ}{\pi a^2}$$

$$= 2^{3/2} \frac{kQ}{\pi a^2}$$

A	<del><math>kQ/(\pi a^2)</math></del>	F	$kQ/(\pi a^2)$
B	$2kQ/(\pi^2 a^2)$	G	$2kQ/(\pi a^2)$
C	$kQ/(2^{1/2} \pi^2 a^2)$	H	$kQ/(2^{1/2} \pi a^2)$
D	$2^{1/2} kQ/(\pi^2 a^2)$	I	$2^{1/2} kQ/(\pi a^2)$
10	E	<b>J</b>	$2^{3/2} kQ/(\pi a^2)$

For problems 17, 18, 19 consider the figure shown here. In all these problems,  $\lambda$  is a positive number, and  $r$  is the radial distance from the center of the concentric cylinders. There are two conducting, concentric, cylindrical shells, one between  $R$  and  $2R$  has a total linear charge density (charge per unit length)  $-3\lambda$ , and the one between  $3R$  and  $4R$  has a total linear charge density  $+2\lambda$ . There is no charge within the inner conductor. The system is in static equilibrium.



17. The radial electric field in the region  $2R < r < 3R$  is [positive  $r$  being radial outward,  $k=1/(4\pi\epsilon_0)$ ]:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = E (2\pi r l) = \frac{(2\lambda l)}{\epsilon_0}$$

$$\Rightarrow E = \frac{\lambda}{\pi \epsilon_0 r} = \frac{4\lambda}{(4\pi\epsilon_0) r}$$

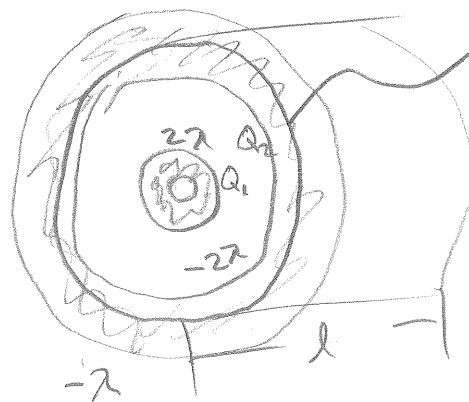
$$\Rightarrow E = \frac{4k\lambda}{r}$$

A	$k\lambda / (4\pi r)$	F	$-k\lambda / (4\pi r)$
B	$k\lambda / (2\pi r)$	G	$-k\lambda / (2\pi r)$
C	$k\lambda / (\pi r)$	H	$-k\lambda / (\pi r)$
D	$2k\lambda / (\pi r)$	I	$-2k\lambda / (\pi r)$
E	$5k\lambda / (\pi r)$	J	0

← not in list



18. The linear charge density at  $r=3R$  on the surface of the inner part of the outer conductor is:

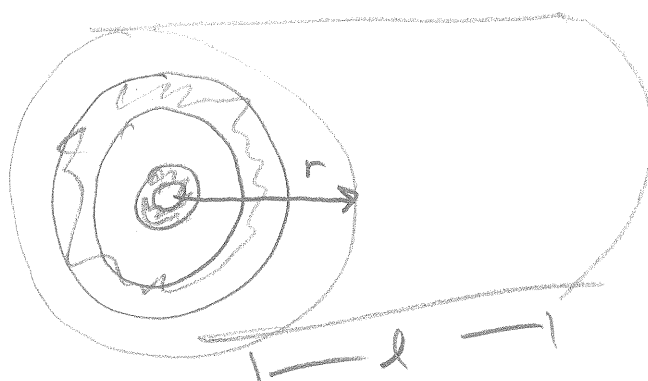


$\oint \vec{E} \cdot d\vec{A} = 0$  for conductor  
 $\therefore Q_{\text{enc}} = 0 \Rightarrow Q_1 + Q_2 = 0$   
 $l(\text{sum of } \lambda\text{'s}) = 0$   
 $\Rightarrow \text{sum of } \lambda\text{'s} = 0$   
 $\Rightarrow \boxed{-2\lambda}$  on inside of outer conductor

$-2\lambda + (-\lambda) = -3\lambda$  total

A	$\lambda/2$	F	$-\lambda/2$
B	$\lambda$	G	$-\lambda$
C	$3\lambda/2$	H	$-3\lambda/2$
D	$2\lambda$	I	$-2\lambda$
E	$4\lambda$	J	0

19. The electric field for the region  $r > 4R$  is:



$\oint \vec{E} \cdot d\vec{A} = E(2\pi r l)$   
 $= \frac{Q_{\text{enc}}}{\epsilon_0} = \frac{\lambda(2\lambda - 3\lambda)l}{\epsilon_0}$

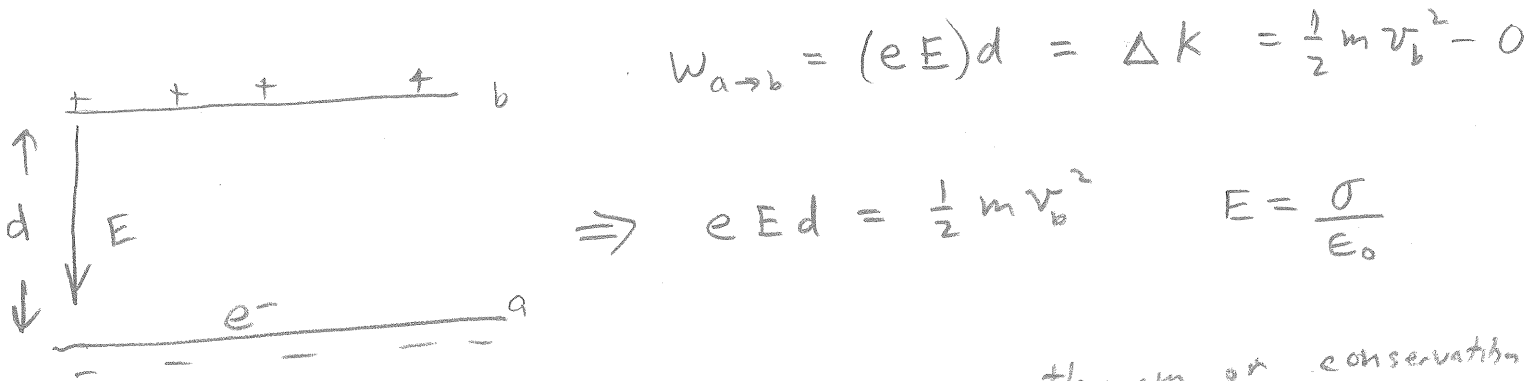
$\Rightarrow E = \frac{-\lambda}{2\pi\epsilon_0 r}$

A	$k\lambda/(4\pi r)$	F	$-k\lambda/(4\pi r)$
B	$k\lambda/(2\pi r)$	G	$-k\lambda/(2\pi r)$
C	$k\lambda/(\pi r)$	H	$-k\lambda/(\pi r)$
D	$2k\lambda/(\pi r)$	I	$-2k\lambda/(\pi r)$
E	0	J	$-5k\lambda/(\pi r)$

$= -\frac{2}{(4\pi\epsilon_0)} \frac{\lambda}{r}$   
 $= -\frac{2k\lambda}{r}$

The enclosed charge is less than zero  
 $E$  must be  $< 0$ .

20. Two infinite parallel conducting plates have equal but opposite charge density with magnitude  $\sigma=10^{-12}$  C/m<sup>2</sup> on them. The plates are separated by a distance  $d=1$  cm. An electron starts at rest on the negatively charged plate and moves to the other plate. You may ignore the effect of gravity. What is the speed of the electron when it reaches the other plate? [the mass of the electron is  $m_e=1.9 \times 10^{-31}$  kg, the charge on the electron is  $-e=-1.6 \times 10^{-19}$  C,  $\epsilon_0=8.85 \times 10^{-12}$  C<sup>2</sup>/(N m<sup>2</sup>)]



You can use the work kinetic Energy theorem or conservation of energy to get  $eEd = \frac{1}{2} m_e v_b^2$

$$\Rightarrow v_b^2 = \frac{2eEd}{m_e} = \frac{2e(\frac{\sigma}{\epsilon_0})d}{m_e} \Rightarrow v_b = \sqrt{\frac{2e\sigma d}{m_e \epsilon_0}}$$

$$\Rightarrow v_b = \sqrt{\frac{2 \cdot 1.6 \times 10^{-19} \text{ C} \cdot (10^{-12} \text{ C/m}^2) \cdot (10^{-2} \text{ m})}{(1.9 \times 10^{-31} \text{ kg}) \cdot (8.85 \times 10^{-12} \frac{\text{C}^2}{\text{Nm}^2}) \frac{\text{N}}{\text{kg} \cdot \text{m/s}^2}}}$$

$$\approx 43,624.10734 \text{ m/s}$$

A	11.1 m/s	F	19,900 m/s
B	13.4 m/s	<b>G</b>	43,600 m/s
C	220 m/s	H	1.33x10 <sup>6</sup> m/s
D	234 m/s	I	1.99x10 <sup>8</sup> m/s
E	14,100 m/s	J	3.97x10 <sup>8</sup> m/s