第 36 届全国中学生物理竞赛复赛理论考试试题解答

40 a R ( )

a G

r O m

$\frac{m}{5}$ H

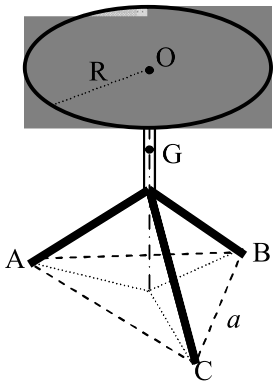
g

1

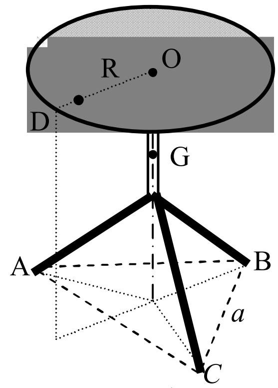
2 D

OD AC

b



a



b

1 O O y .

y_{CM}

$$y_{\mathrm{CM}} ! \frac{\frac{4m}{5}\frac{H}{2} \quad (\pi r^2 h)\frac{h}{2}}{m \quad (\pi r^2 h)} \qquad (1)\ 5$$

h . $'' ! \ \pi r^2$ (1)

$$y_{\mathrm{CM}} ! \frac{\frac{4m}{5}\frac{H}{2} \quad '' \frac{h^2}{2}}{m \quad ''h}$$

.

$y_{\mathrm{CM}}(h ! h_{\max}) ! (y_{\mathrm{CM}})_{\min}$

$$\left.\frac{\mathrm{d}y_{\mathrm{CM}}}{\mathrm{d}h}\right|_{h ! h_{\max}} ! 0 \qquad (2)\ 5$$

(1)(2)

$$h_{\max} ! \frac{m}{''} \%1 \& \sqrt{1 \quad \frac{4}{5}\frac{H''}{m}} \qquad (3)$$

$$h_{\max} ! \frac{m}{''} \overset{+}{\underset{/}{-}} \sqrt{1 \quad \frac{4}{5} \frac{''H}{m}} \%1 \overset{,}{\underset{0}{.}}$$ (4) 3

$$! \frac{m}{\pi r^2} \overset{+}{\underset{/}{-}} \sqrt{1 \quad \frac{4\pi}{5} \frac{r^2 H}{m}} \%1 \overset{,}{\underset{0}{.}}$$

[

.

$y_{\mathrm{CM}}(h \,!\, h_{\max}) \,!\, (y_{\mathrm{CM}})_{\min}$. (1)

$$y_{\mathrm{CM}} \; ! \; \frac{\frac{2mH}{5} \quad \frac{m^2}{2''}}{m \quad ''h} \quad \frac{m \quad ''h}{2''} \% \frac{m}{''}$$

$$y_{\mathrm{CM}} \; 1 \; 2\sqrt{\frac{\frac{2mH}{5} \quad \frac{m^2}{2''}}{m \quad ''h} \frac{m \quad ''h}{2''}} \% \frac{m}{''} \; ! \; 2\sqrt{\frac{\frac{2mH}{5} \quad \frac{m^2}{2''}}{2''}} \% \frac{m}{''} \; ! \; (y_{\mathrm{CM}})_{\min}$$ (2) 5

h

$$\frac{m \quad ''h}{2''} \; ! \; \frac{\frac{2mH}{5} \quad \frac{m^2}{2''}}{m \quad ''h}$$ (3)

$$h \,!\, h_{\max} ! \frac{m}{''} \overset{+}{\underset{/}{-}} \sqrt{1 \quad \frac{4}{5} \frac{''H}{m}} \%1 \overset{,}{\underset{0}{.}}$$ (4) 3

$$! \frac{m}{\pi r^2} \overset{+}{\underset{/}{-}} \sqrt{1 \quad \frac{4\pi}{5} \frac{r^2 H}{m}} \%1 \overset{,}{\underset{0}{.}}$$

$h_{\max}$.

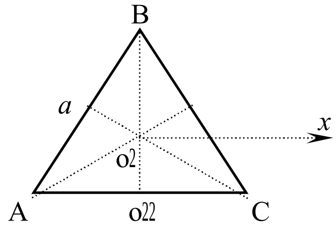
]

2 M.

D

a b N_{A} N_{B} N_{C}

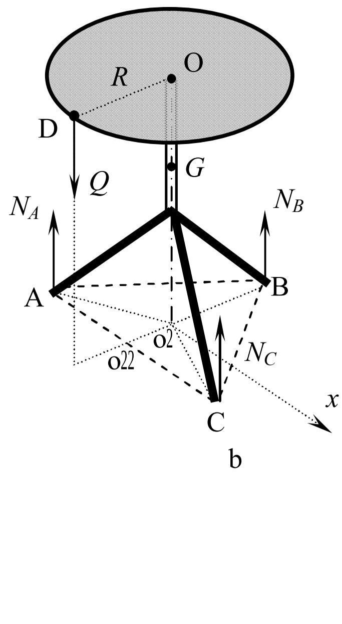
A B C



a

$$\overline{\text{o2A}} \; ! \; \overline{\text{o2B}} \; ! \; \frac{a/2}{\cos 303} \; ! \; \frac{a}{\sqrt{3}}$$ (5) 3

$$\overline{\text{o2o22}} \; ! \; \frac{a}{2} \tan 303 \; ! \; \frac{a}{2\sqrt{3}}$$ (6) 3



b

$N_{\mathrm{A}} \quad N_{\mathrm{B}} \quad N_{\mathrm{C}} \% Q \% P \; ! \; 0$ (7) 3

$N_{\mathrm{A}} \; ! \; N_{\mathrm{C}}$ (8) 3

$Q \; ! \; mg \quad ''h_{\max} g \quad P \; ! \; Mg$. (7) (8)

$2N_{\mathrm{A}} \quad N_{\mathrm{B}} \% Q \% P \; ! \; 0$

x

$Q\,4R \% r5 \quad N_{\mathrm{B}} \overline{\text{o2B}} \% (N_{\mathrm{A}} \quad N_{\mathrm{C}}) \overline{\text{o2o22}} \; ! \; 0$ (9) 5

$R2 \; ! \; R \% r$ (5)(6)(9)

$$QR2 \quad N_{\mathrm{B}}\frac{a}{\sqrt{3}} \% 2N_{\mathrm{A}}\frac{a}{2\sqrt{3}} \; ! \; 0$$

[

AC

$$Q(R2 \% \overline{ꝏ2}) \quad N_{\mathrm{B}}(\overline{ꝏB} \quad \overline{ꝏ2}) \% P\overline{ꝏ2} \; ! \; 0 \qquad (9)\ 5$$

$$Q(R2 \% \frac{a}{2\sqrt{3}}) \quad N_{\mathrm{B}}(\frac{a}{\sqrt{3}} \quad \frac{a}{2\sqrt{3}}) \% P\frac{a}{2\sqrt{3}} \; ! \; 0$$

]

$$N_{\mathrm{B}} \; ! \; \frac{(a \% 2\sqrt{3}R2)Q \quad aP}{3a}$$

$$! \; \begin{matrix}\#_+ \\ ' \\ )/\end{matrix} 1 \% 2\sqrt{3}\frac{R \% r}{a} \begin{matrix}, \\ 0\end{matrix} \sqrt{1 \quad \frac{4\pi}{5}\frac{r^2 H}{m}} m \quad M \begin{matrix}\$ \\ (\\ *\end{matrix} \frac{g}{3} \qquad (10)$$

$$N_{\mathrm{A}} \; ! \; N_{\mathrm{C}} \; ! \; \frac{(a \quad \sqrt{3}R2)Q \quad aP}{3a}$$

$$! \; \begin{matrix}\#_+ \\ ' \\ )/\end{matrix} 1 \quad \sqrt{3}\frac{R \% r}{a} \begin{matrix}, \\ 0\end{matrix} \sqrt{1 \quad \frac{4\pi}{5}\frac{r^2 H}{m}} m \quad M \begin{matrix}\$ \\ (\\ *\end{matrix} \frac{g}{3} \qquad (11)$$

(10) N_{B} 6 0

$$M \; 6 \; \frac{2\sqrt{3}(R \% r) \% a}{a}\sqrt{1 \quad \frac{4\pi}{5}\frac{r^2 H}{m}} m \qquad (12)$$

(7)(10)(11)

$$7N_{\mathrm{B}} \; ! \; \frac{(a \% 2\sqrt{3}R2)Q \quad aP}{3a} \% \frac{P \quad Q}{3}$$

$$! \; \% \frac{2\sqrt{3}}{3}\frac{R \% r}{a}\sqrt{1 \quad \frac{4\pi}{5}\frac{r^2 H}{m}} mg \qquad (13)\ 4$$

50

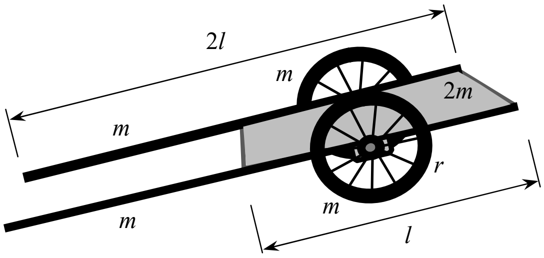
a

r m

l

$2m$

$2l$ m



a.

g

1

2

ϑ

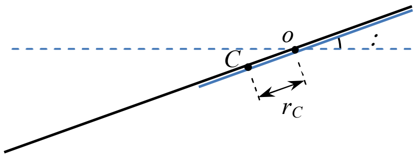
1

$$J_1 \;!\; 2[\frac{1}{12}m(2l)^2 \quad m(\frac{1}{2}l)^2] \;!\; 2(\frac{4}{12}m^2 \quad \frac{1}{4}ml^2) \;!\; \frac{7}{6}ml^2$$

$$J_2 \;!\; \frac{1}{12}2ml^2 \;!\; \frac{1}{6}ml^2$$

$$J \;!\; J_1 \quad J_2 \;!\; \frac{7}{6}ml^2 \quad \frac{1}{6}ml^2 \;!\; \frac{4}{3}ml^2 \qquad (1)\ 4$$

r_C a



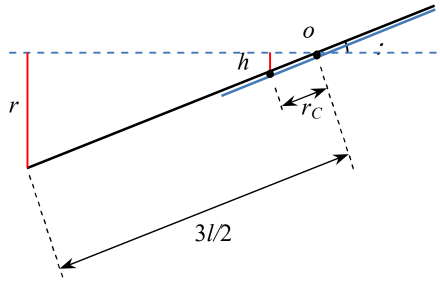
a

$$r_C \;!\; \frac{2m\frac{l}{2}}{4m} \;!\; \frac{l}{4} \qquad (2)\ 2$$

ϑ

$$\frac{1}{2}J\vartheta^2 \;!\; 4mgh \qquad (3)\ 2$$

h b



b

$$\frac{h}{r_C} \;!\; \frac{r}{3l/2}$$

(2)

$$h \;!\; \frac{2r}{3l}\frac{l}{4} \;!\; \frac{r}{6}$$

(1)(3)

$$\vartheta \;!\; \frac{\sqrt{gr}}{l} \qquad (4)\ 2$$

2

$$v_{C1} \;!\; \vartheta r_C \;!\; \frac{\sqrt{gr}}{l}\frac{l}{4} \;!\; \frac{\sqrt{gr}}{4}$$

$\sin : ! \dfrac{2r}{3l} \quad \cos : ! \dfrac{\sqrt{9l^2 \% 4r^2}}{3l}$

$v_{C1x} ! v_{C1} \sin : ! \dfrac{\sqrt{gr}}{4} \dfrac{2r}{3l} ! \dfrac{r\sqrt{gr}}{6l}$ (5) 2

$v_{C1y} ! \% v_{C1} \cos : ! \% \dfrac{\sqrt{gr}}{4} \dfrac{\sqrt{9l^2 \% 4r^2}}{3l} ! \% \dfrac{\sqrt{gr(9l^2 \% 4r^2)}}{12l}$ (6) 2

$7t$

.

.

$N2$ v_0 v_0 1 0 .

$\int_0^{7t} (\% 8N2) \,\mathrm{d}t ! 6mv_0 \% 4mv_{C1x}$ (7) 2

$\int_0^{7t} N2 \,\mathrm{d}t ! 0 \% (\% 4mv_{C1y})$ (8) 2

(8) (7) .

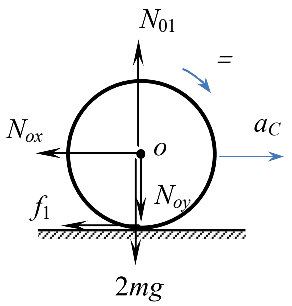
(7)(8)

$6mv_0 ! 4mv_{C1x} \% 84mv_{C1y} ! 4mv_{C1} \sin : \% 84mv_{C1} \cos :$

$v_0 ! \dfrac{2}{3}(\sin : \% 8\cos :)v_{C1} ! \dfrac{2}{3}(\sin : \% 8\cos :)\dfrac{\sqrt{gr}}{4} ! (\sin : \% 8\cos :)\dfrac{\sqrt{gr}}{6}$

$8 \; 1 \; \tan : ! \dfrac{2r}{\sqrt{9l^2 \% 4r^2}}$

$s = 0$ (9) 2



c

$8 < \tan : ! \dfrac{2r}{\sqrt{9l^2 \% 4r^2}}$

.

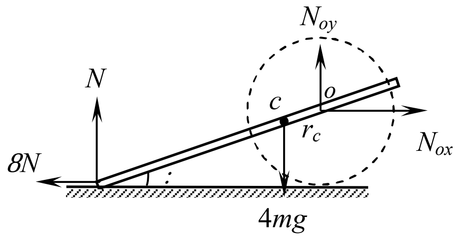
I.

c N_{01}

N_{ox} N_{oy}

$f_1 ! 8N_{01}$.

d



d

N .

$f ! \% 8(N \quad N_{01}) ! \% 8(6mg)$ (10) 2

a_C

$a_C ! \dfrac{f}{6m} ! \% 8g$ (11) 2

$N_{ox} \% 8N ! 4ma_C$ (12) 1

$N \quad N_{oy} \% 4mg ! 0$ (13) 1

$$8N\frac{5l}{4}\sin : \quad N\frac{5l}{4}\cos : \quad N_{ox}\frac{l}{4}\sin : \% N_{oy}\frac{l}{4}\cos : \ ! \ 0 \qquad (14)\ 2$$

(11) (12) (13)

$$N_{ox} \ ! \ 8N \quad 4m(\% 8g) \ ! \ 8N \% 4 8mg$$

$$N_{oy} \ ! \ 4mg \% N$$

(14)

$$8N\frac{5l}{4}\sin : \quad N\frac{5l}{4}\cos : \quad (8N \% 4 8mg)\frac{l}{4}\sin : \% (4mg \% N)\frac{l}{4}\cos : \ ! \ 0$$

$$N \ ! \ \frac{2}{3}mg$$

$$N_{ox} \ ! \ 8\frac{2}{3}mg \% 4 8mg \ ! \ \%\frac{10}{3} 8mg$$

$$N_{oy} \ ! \ 4mg \% \frac{2}{3}mg \ ! \ \frac{10}{3}mg$$

$$N_0 \% 2mg \% N_{oy} \ ! \ 0 \qquad (15)\ 2$$

$$8N_0 r \ ! \ 2mr^2 = \qquad (16)\ 2$$

(15)

$$N_0 \ ! \ 2mg \quad N_{oy} \ ! \ 2mg \quad \frac{10}{3}mg \ ! \ \frac{16}{3}mg$$

(16)

$$= \ ! \ \frac{8N_0 r}{2mr^2} \ ! \ \frac{8}{2mr}\frac{16}{3}mg \ ! \ \frac{8 8g}{3r}$$

t

$$9 r \ ! \ =tr \ ! \ v \ ! \ v_0 \quad a_C t \qquad (17)\ 2$$

$$(\beta r \% a_C)t = v_0$$

$$t \ ! \ \frac{v_0}{(\beta r \% a_C)} \ ! \ \frac{(\sin\theta - \mu\cos\theta)}{22\mu}\sqrt{\frac{r}{g}}$$

$$v_1 \ ! \ v_0 \quad a_C t \ ! \ (\sin : \% 8\cos :)\frac{\sqrt{gr}}{6} \% 8g\frac{(\sin : \% 8\cos :)}{22 8}\sqrt{\frac{r}{g}} \qquad (18)\ 2$$

$$! \ \frac{4\sqrt{gr}}{33}(\sin : \% 8\cos :)$$

s_1

$$v_1^2 \% v_0^2 \ ! \ 2a_C s_1$$

$$s_1 \ ! \ \frac{v_1^2 \% v_0^2}{2a_C} \ ! \ \frac{\left(\frac{4\sqrt{gr}}{33}(\sin : \% \ 8\cos :)\right)^2 \% \left((\sin : \% \ 8\cos :)\frac{\sqrt{gr}}{6}\right)^2}{\%2\,8g} \qquad (19)\ 2$$

$$! \ \frac{57r}{8712\,8}(\sin : \% \ 8\cos :)^2 \ ! \ \frac{57r}{78408\,8l^2}(2r \% \ 8\sqrt{9l^2 \% 4r^2})^2$$

II.

e N_{02}

N_{ox2} N_{oy2}

f_2

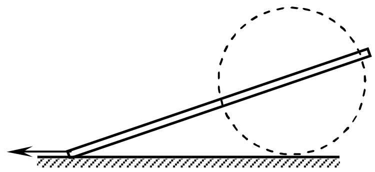
f N_2 .

$$f_2 \% N_{ox2} \ ! \ 2ma_{C2} \qquad (20)\ 1$$

$$\%f_2 r \ ! \ 2mr^2 =_2 \qquad (21)\ 1$$

$$a_{C2} \ ! \ =_2 r \qquad (22)\ 2$$

(20)(21)(22)



$$N_{ox2} \ ! \ \%4ma_{C2}$$

$$N_{ox2} \% \ 8N_2 \ ! \ 4ma_{C2}$$

$$a_{C2} \ ! \ \%\frac{8N_2}{8m}$$

$$N_{ox2} \ ! \ \frac{8N_2}{2}$$

$$N_{oy2} \ ! \ 4mg \% N_2$$

C

$$8N_2\frac{5l}{4}\sin : \quad N_2\frac{5l}{4}\cos : \quad N_{ox2}\frac{l}{4}\sin : \% N_{oy2}\frac{l}{4}\cos : \ ! \ 0$$

N_{ox2} N_{oy2}

$$8N_2\frac{5l}{4}\sin : \quad N_2\frac{5l}{4}\cos : \quad \frac{8N_2}{2}\frac{l}{4}\sin : \% (4mg \% N_2)\frac{l}{4}\cos : \ ! \ 0$$

$$N_2 \ ! \ \frac{8mg}{11\,8\tan : \quad 12}$$

$$N_{ox2} \ ! \ \frac{4\,8mg}{11\,8\tan : \quad 12}$$

$$N_{oy2} \ ! \ \frac{4(11\,8\tan : \quad 10)mg}{11\,8\tan : \quad 12}$$

$$a_{C2} \; ! \; \% \frac{8N_2}{8m} \; ! \; \% \frac{8g}{11 8 \tan : \quad 12} \qquad (23) \quad 4$$

s_2

$0 \% v_1^2 \; ! \; 2a_{C2}s_2$

$$s_2 \; ! \; \frac{\% v_1^2}{2a_{C2}} \; ! \; \frac{(11 8 \tan : \quad 12)}{2 8 g} \,\#\, \frac{4\sqrt{gr}}{33}(\sin : \% \; 8\cos :)\$^2$$

$$! \; \frac{8gr}{1089\, 8g}(\sin : \% \; 8\cos :)^2 (11 8 \tan : \quad 12) \qquad (24)\; 2$$

$$! \; \frac{16r}{9801\, 8l^3}(2r \% \; 8\sqrt{9l^2 \% 4r^2})^2 \frac{11 8r \quad 6\sqrt{9l^2 \% 4r^2}}{\sqrt{9l^2 \% 4r^2}}$$

$s \; ! \; s_1 \quad s_2$

$$! \; \frac{57r}{78408\, 8l^2}(2r \% \; 8\sqrt{9l^2 \% 4r^2})^2 \quad \frac{16r}{9801\, 8l^3}(2r \% \; 8\sqrt{9l^2 \% 4r^2})^2 \frac{11 8r \quad 6\sqrt{9l^2 \% 4r^2}}{\sqrt{9l^2 \% 4r^2}} \qquad (25)2$$

$$! \; \# \frac{57}{78408} \quad \frac{16(11 8r \quad 6\sqrt{9l^2 \% 4r^2})}{9801\sqrt{9l^2 \% 4r^2}} \$ \frac{(2r \% \; 8\sqrt{9l^2 \% 4r^2})^2 r}{8l^2}$$

50 . 1 10 (1) 4 (2)(3)(4) 2
2 40 (5)(6)(7)(8)(9)(10)(11) 2 (12)(13) 1 (14) (15)(16)(17)(18)(19)
2 (20)(21) 1 (22) 2 (23) 4 (24)(25) 2 .

40 a

:

L *b*

″ *d* *d*

m *m*

d

R

I

g 8_0

1

2

3

4

5 : = 03

1 *d*

r^2

$$B \; ! \; \frac{8_0 I}{4\pi r^2} \quad \frac{8_0 I}{4\pi(d \quad 2b \,\%\, r^2)}$$

(18) W_1 W_2 W_3

$$W_1 = \int_0^T ''I^2\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)t^2\,\mathrm{d}t$$

$$= \frac{''I^2}{3}\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)T^3$$

$$= \frac{2\sqrt{2}\,''I^2}{3}L^{3/2}\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)^{-1/2}$$

$$W_2 = I^2RT = I^2R\sqrt{2L}\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)^{-1/2}$$

$$W_3 = \frac{\mu_0 I^2}{2\pi}\ln\frac{d+b}{b}\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)T^2 = \frac{\mu_0 I^2 L}{\pi}\ln\frac{d+b}{b}$$

$$W = W_1 + W_2 + W_3$$

$$= \frac{2\sqrt{2}\,''I^2}{3}L^{3/2}\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)^{-1/2}$$

$$+ I^2R\sqrt{2L}\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)^{-1/2} + \frac{\mu_0 I^2 L}{\pi}\ln\frac{d+b}{b} \quad (19)\ 3$$

$$= \sqrt{2L}I^2\left(\frac{2''L}{3} + R\right)\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right)^{-1/2} + \frac{\mu_0 I^2 L}{\pi}\ln\frac{d+b}{b}$$

5

$$E_{k\max} = \frac{1}{2}mv_{\max}^2 = mL\left(\frac{\mu_0 I^2}{2\pi m}\ln\frac{d+b}{b} - g\sin\theta\right) = \frac{\mu_0 I^2 L}{2\pi}\ln\frac{d+b}{b} - mgL\sin\theta \quad (20)$$

$\theta = 0$ 3

$$E_{k\max} = \frac{\mu_0 I^2 L}{2\pi}\ln\frac{d+b}{b} \quad (21)\ 2$$

$$W = \frac{\mu_0 I^2 L}{\pi}\ln\frac{d+b}{b} \quad (22)\ 2$$

$$\eta = \frac{E_{k\max}}{W} = 50\% \quad (23)\ 2$$

40 . 1 8 (1) 4 (2)(3) 2

2 6 (5) 2 (7) 4

3 14 (10) 4 (11)(12) 2 (15) 4 (17) 2

4 6 (18)(19) 3

5 6 (21)(22)(23) 2 .

40 2016 9 G20

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b . l

V_0 S.

v_s A

$$v_s\ !\ \sqrt{\frac{A}{}}$$

A $7p$ V

$$A\ !\ \%\frac{7p}{7V\ /\ V}\ !\ \%V\frac{7p}{7V}$$

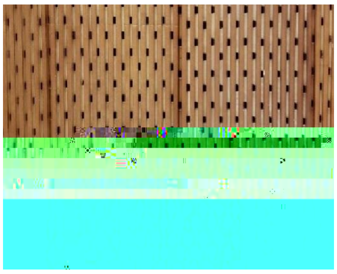
273K 1atm ! 1.01B10^5 Pa ( ) M_{mol} =

29.0 g/mol $C\ !\ \frac{7}{5}$ R ! 8.31 J/(K mol) .

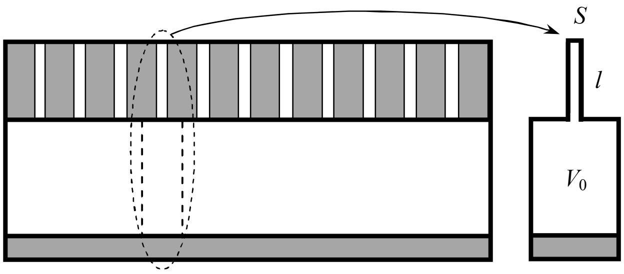
1 v_s

2 v_s S l V_0

3 120 Hz 200 Hz



a.



b.

1

$$pV\ !\ \frac{M}{M_{mol}}RT \qquad (1)\ 4$$

p V T M M_{mol}

(1)

$$!\ \frac{M}{V}\ !\ \frac{M_{mol}p}{RT}$$

$$!\ \frac{M_{mol}p}{RT}\ !\ \frac{29.0\text{B}10^{\%3}\text{kg/mol}\,\text{B}1.01\text{B}10^5\text{Pa}}{8.31\text{J/(K mol)}\,\text{B}273\text{K}}\ !\ 1.29\ \text{kg/m}^3 \qquad (2)\ 2$$

$$pV^C\ !$$

C

$$7pV^C\quad CpV^{C\%1}7V\ !\ 0 \qquad (3)\ 4$$

(3)

$$A \; ! \; \%V\frac{7p}{7V} \; ! \; Cp \qquad (4)\ 4$$

$$v_s \; ! \; \sqrt{\frac{A}{}} \; ! \; \sqrt{\frac{Cp}{}}$$

$$v_s \; ! \; \sqrt{\frac{Cp}{}} \; ! \; \sqrt{\frac{7}{5}\mathrm{B}\frac{1.01\mathrm{B}10^5\,\mathrm{Pa}}{1.29\mathrm{kg/m^3}}} \; ! \; 331\ \mathrm{m/s} \qquad (5)4$$

2

$$m = \; Sl \qquad (6)$$

.

x

$$7V \; ! \; Sx \qquad (7)$$

(3)

$$7p \; ! \; \%\frac{Cp7V}{V} \qquad (8)\ 2$$

$$F \; ! \; S7p \; ! \; \%\frac{CpS^2x}{V} \qquad (9)4$$

$$\%\frac{CpS^2}{V}x \; ! \; m\ddot{x} \; ! \; Sl\ddot{x} \qquad (10)$$

(10)

$$\ddot{x} \; ! \; \%9^2x \qquad (11)4$$

9

$$9 \; ! \; \sqrt{\frac{CpS}{lV}} \qquad (12)$$

$v_s \; ! \; \sqrt{\frac{Cp}{}}$ (10)

$$f_0 \; ! \; \frac{9}{2\pi} \; ! \; \frac{v_s}{2\pi}\sqrt{\frac{S}{lV}} \; ! \; \frac{v_s}{2\pi}\sqrt{\frac{S}{lV_0}} \qquad (13)\ 6$$

$V \; ! \; V_0$.

3 f_{01} f_{02}

$$\frac{f_{01}}{f_{02}} \; ! \; \frac{120\mathrm{Hz}}{200\mathrm{Hz}} \; ! \; 0.60 \qquad (14)$$

(13)

$$f_{01} \; ! \; \frac{v_s}{2\pi}\sqrt{\frac{S_1}{lV_0}} \qquad f_{02} \; ! \; \frac{v_s}{2\pi}\sqrt{\frac{S_2}{lV_0}} \qquad (15)$$

S_1 S_2 . (15)

$$\frac{\sqrt{S_1}}{\sqrt{S_2}} \; ! \; \frac{f_{01}}{f_{02}} \qquad (16)$$

$$\frac{S_1}{S_2} = \left(\frac{f_{01}}{f_{02}}\right)^2 = 0.36$$ (17) 6

40 . 1 18 (1) 4 (2) 2 (3)(4)(5) 4

2 16 (8) 2 (9)(11) 4 (13) 6

3 6 (17) 6 .

$$o_2 \;!\; i_1 \% D \;!\; \frac{(2n_0 \% n)D}{2(n \% n_0)} \;!\; \frac{(2\,\mathrm{B}\,1.00 \% 1.50)\,\mathrm{B}\,3.00\ \mathrm{mm}}{2(1.50 \% 1.00)} \;!\; 1.50\ \mathrm{mm} \qquad (8)4$$

o_2

$$o_2 \;!\; \frac{(n \% 2n_0)D}{2(n \% n_0)} \;!\; \%1.50\mathrm{mm}$$

r_2

$$r_2 \;!\; \% \frac{D}{2}$$

(7) i_2

$$i_2 \;!\; \frac{(2n_0 \% n)D}{4(n \% n_0)} \;!\; 0.75\ \mathrm{mm} \qquad (9)4$$

O 0.75mm.

3

$$f_{\mathrm{e}} \;!\; \frac{(2n_0 \% n)D}{4(n \% n_0)} \quad \frac{D}{2} \;!\; \frac{nD}{4(n \% n_0)} \;!\; \frac{1.50\,\mathrm{B}\,3.00\ \mathrm{mm}}{4(1.50 \% 1.00)} \;!\; 2.25\ \mathrm{mm} \qquad (10)4$$

d

$$\frac{\frac{d}{2}}{\sqrt{\left(\frac{d}{2}\right)^2 \quad \left(\frac{nD}{4(n \% n_0)}\right)^2}} \;!\; \frac{1}{\sqrt{1 \quad \left(\frac{nD}{2d(n \% n_0)}\right)^2}} \;!\; \sin \theta \qquad (11)4$$

n_0 ! 1.00 n ! 1.50

n_0E ! n=

= ! $\frac{2}{3}E$ (5)4

C ! $\frac{1}{3}E$:2 ! 2C (6)6

:2 ! HBFO2 .

HCBF ! C ! HFCB (7)2

HBO2C ! E% :2 ! C (8)4

7BO2C 7FCB .

$\overline{\text{O2O}}$! $\overline{\text{OC}}$

$\overline{\text{OF}}$! $\overline{\text{FC}}$! $\frac{D}{4}$! 0.75 mm (9)4

O O2C .

3 d

HBFO2

:2 ! : ! 0.17 (10)4

(6)(10)

E ! $\frac{d}{D}$! $\frac{3}{2}$: (11)4

(10)(11)

d ! $\frac{3}{2}D$ B 0.17 ! 0.76 mm (12)4

0.76 mm .

]

[

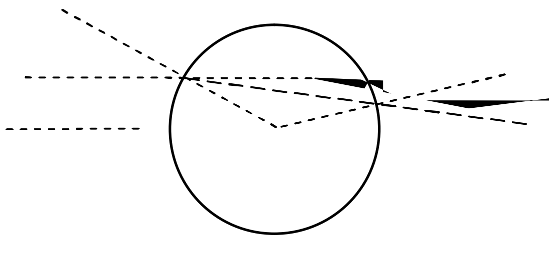
2 b O2 A

E HO2AB I = B O2A=O2B

B HO2BA ! = E F

F AB C .

$n_0 \sin E$! $n \sin$ = (5)4



7BO2F

$\frac{\overline{\text{O2F}}}{\sin E}$! $\frac{\overline{\text{O2B}}}{\sin :2}$ (6)6

:2 ! HBFO2

. HBO2C ! C

E C ! 2= (7)2

:2 ! E%C ! 2(E% =) (8)4

(6)(8)

$$\overline{\text{O2F}} \; ! \; \frac{\sin E}{\sin[2(E \% =)]}\frac{D}{2}$$

$$! \; \frac{1}{+1 \% \frac{\sin^2 E}{2n_0^2} \% \frac{1}{n_0} \quad \frac{1}{2n_0}\sin^2 E' + (1 \% \frac{\sin^2 E}{2})(1 \% \frac{\sin^2 E}{2n_0^2}) \quad \frac{\sin^2 E}{n_0},}\frac{D}{4}$$

$$\overline{\text{OF}} \; ! \; \overline{\text{O2F}} \% \frac{D}{2} \; ! \; +\frac{\sin E}{\sin[2(E \% =)]} \% 1,\frac{D}{2}$$

(9)4

$$\text{G} \; \#\frac{n}{2(n \% n_0)} \% 1\$\frac{D}{2} \; ! \; \frac{(2n_0 \% n)D}{4(n \% n_0)} \; ! \; 0.75\text{mm}$$

$\text{O}(E^2)$.

3 *d*

HBFO2

: :

40 π μ μ $\bar{\nu}_{\mu}$

–

$$\gamma'_\mu = \frac{1}{\sqrt{1 - \frac{u'^2_\mu}{c^2}}}$$

u'_μ μ S2 (1)(3)(4)

$$E'_\nu = p'_\nu c = p'_\mu c = \sqrt{E'^2_\mu - (m_\mu c^2)^2}$$
$$= m_\pi c^2 - \gamma'_\mu m_\mu c^2 = (m_\pi - m_\mu)c^2 - m_\mu c^2(\gamma'_\mu - 1)$$

$$E'^2_\mu - (m_\mu c^2)^2 = [(m_\pi - m_\mu)c^2]^2 - 2(m_\pi - m_\mu)m_\mu c^4(\gamma'_\mu - 1) + [m_\mu c^2(\gamma'_\mu - 1)]^2$$

$$(m_\mu c^2)^2(\gamma'^2_\mu - 1) = [(m_\pi - m_\mu)c^2]^2 - 2(m_\pi - m_\mu)m_\mu c^4(\gamma'_\mu - 1) + [m_\mu c^2(\gamma'_\mu - 1)]^2$$

$$\gamma'_\mu = 1 + \frac{(m_\pi - m_\mu)^2}{2m_\pi m_\mu} = 1 + \frac{(139.57061 - 105.65837)^2}{2 \times 139.57061 \times 105.65837} = 1.0390 \qquad (5)4$$

8 S2

$$u'_\mu = c\sqrt{1 - \frac{1}{\gamma'^2_\mu}} = c\sqrt{1 - \frac{1}{1.0390^2}} = 0.2714c \qquad (6)2$$

]

S π μ :

S2 :2. S μ

u

$$u_\mu = \frac{\sqrt{u'^2_\mu + v^2 + 2u'_\mu v\cos\theta' - \left(\frac{u'_\mu v}{c}\right)^2 \sin^2\theta'}}{1 + \frac{u'_\mu v}{c^2}\cos\theta'}$$

$$u_\mu = c\sqrt{1 - \frac{\left(1 - \frac{u'^2_\mu}{c^2}\right)\left(1 - \frac{v^2}{c^2}\right)}{\left(1 + \frac{u'_\mu v}{c^2}\cos\theta'\right)^2}}$$

π μ u_{min} u_{max} $\theta' = 0$

$\theta' = \pi$ $\theta = 0$ $\theta = \pi$.

$$u_\mu \cos\theta = \frac{u'_\mu \cos\theta' + v}{1 + \frac{u'_\mu v}{c^2}\cos\theta'}$$

π μ u_{min} u_{max}

$$u_{\mu\min} = \frac{-u'_\mu + v}{1 + \frac{(-u'_\mu)v}{c^2}} = \frac{-0.2714 + 0.9650}{1 + (-0.2714) \times 0.9650}c = 0.940c = 2.82 \times 10^8\ \text{m/s} \qquad (7)4$$

$$u_{\mu\max} = \frac{u'_\mu + v}{1 + \frac{u'_\mu v}{c^2}} = \frac{0.2714 + 0.9650}{1 + 0.2714 \times 0.9650}c = 0.980c = 2.94 \times 10^8\ \text{m/s} \qquad (8)4$$

2 μ ρ

$$! \frac{N_t}{N_0} ! 2^{\% \frac{7t}{T_{1/2}}} \qquad (9)4$$

N_0 μ N_t t μ $7t$ μ h ! 10000m

. $7t$ $u_μ$! $u_{μ\,max}$

$$(7t)_{min} ! \frac{h}{u_{μ\,max}} ! \frac{10000m}{0.980 B 3.00 B 10^8 m/s} ! 3.40 B 10^{\%5} s \qquad (10)2$$

$$T_{\frac{1}{2}} ! \frac{T_{\frac{1}{2}}^{(0)}}{\sqrt{1 \% \frac{u_μ^2}{c^2}}} ! \frac{1.523 B 10^{\%6} s}{\sqrt{1 \% 0.980^2}} ! 0.765 B 10^{\%5} s \qquad (11)4$$

μ

$$_{max} ! 2^{\% \frac{(7t)_{min}}{T_{1/2}}} ! 2^{\% \frac{3.40B10^{\%5}}{0.765B10^{\%5}}} ! 0.0459 ! 4.59\% \qquad (12)4$$

[

μ ρ

$$! \frac{N_t}{N_0} ! exp\underset{/}{\overset{+}{-}} \% \frac{7t}{M} \overset{,}{0} \qquad (9)4$$

N_0 μ N_t t μ τ μ . $7t$ μ 10000 m

$u_μ$! $u_{μ\,max}$

$$(7t)_{min} ! \frac{h}{u_{μ\,max}} ! \frac{10000m}{0.980 B 3.0 B 10^8 m/s} ! 3.40 B 10^{\%5} s \qquad (10)2$$

μ M_0 μ $T_{\frac{1}{2}}^{(0)}$

$$M_0 ! \frac{T_{\frac{1}{2}}^{(0)}}{\ln 2} ! \frac{1.523 B 10^{\%6} s}{\ln 2} ! 2.197 B 10^{\%6} s$$

$$M ! \frac{M_0}{\sqrt{1 \% \frac{u_μ^2}{c^2}}} ! \frac{2.197 B 10^{\%6} s}{\sqrt{1 \% 0.980^2}} ! 1.10 B 10^{\%5} s(\quad 1.104 B 10^{\%5} s) \qquad (11)4$$

μ

$$_{max} ! exp\underset{/}{\overset{+}{-}} \% \frac{(7t)_{min}}{M} \overset{,}{0} ! exp\underset{/}{\overset{+}{-}} \% \frac{3.40 B 10^{\%5}}{1.10 B 10^{\%5}} \overset{,}{0} ! e^{\%3.09} ! 0.0455 ! 4.55\%$$

(12)4

$$_{max} ! exp\underset{/}{\overset{+}{-}} \% \frac{(7t)_{min}}{M} \overset{,}{0} ! exp\underset{/}{\overset{+}{-}} \% \frac{3.402 B 10^{\%5}}{1.104 B 10^{\%5}} \overset{,}{0} ! e^{\%3.082} ! 0.0459 ! 4.59\%$$

]

40 . 1 26 (1) 4 (2) 2 (3)(4)(6) 4 [(1) 4 (2) 2 (3) 4 (4) 2 (5) 4 (6) 2] (7)(8) 4 2 14 (9) 4 (10) 2 (11)(12) 4 .

$$U\ !\ Ed\ !\ 150\,\text{MV} \qquad (2)2$$

$E\ !\ 0.15$ MV/m．

$$Q\ !\ CU\ !\ \frac{>_0 \pi r^2 U}{d}\ !\ 26\ \text{C} \qquad (3)2$$

$$W\ !\ \frac{1}{2}QU\ !\ 2.0\,\text{B}\,10^9\ \text{J} \qquad (4)2$$

2 ． h Q

$$E\ !\ 2\,\text{B}\,\frac{1}{4\pi >_0}\frac{Q}{h^2}\ !\ \frac{Q}{2\pi >_0 h^2}$$

3

$$@ ! \frac{Q}{h} ! 4.2\,\mathrm{B}10^{\%4}\,\mathrm{C/m} \qquad (7)2$$

Q ! 2.5 C h ! 6.0 km .

$$E_{r2} ! \frac{@}{2\pi >_0 r2} \qquad (8)4$$

$r2$.

$$D\ \mathrm{G} \frac{@}{\pi >_0 E} ! 5.0\ \mathrm{m} \qquad (9)4$$

E ! 3.0 MV/m .

.

.

$$2\pi r L E ! \frac{\int_0^r 2\pi r2 L \mathrm{d}r2\ (r2)}{>_0} \qquad (10)2$$

$$r>_0 E ! \int_0^r r2 \mathrm{d}r2\ (r2)$$

r

$$>_0 E ! r\ (r) \qquad (11)$$

$$(r) ! >_0 E\ \ r^{\%1} \qquad (12)\ 6$$

4 a . 8

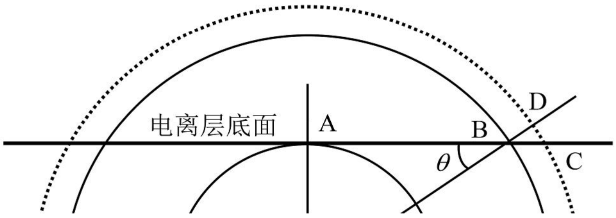
O t ! 0

t ! t_A A

A

.

30kHz<<20MHz



.

t ! t_B B

$\overline{\mathrm{AB}}$! r .

a.

$7t$ B C B

D . c

$$\overline{\mathrm{BD}} ! c7t \qquad (13)\ 2$$

c . B C

$$v ! \frac{\overline{\mathrm{BC}}}{7t} ! \frac{\overline{\mathrm{BC}}}{\overline{\mathrm{BD}}} c ! \frac{c}{\cos :} \qquad (14)\ 2$$

$$\cos : ! \frac{\overline{\mathrm{AB}}}{\overline{\mathrm{OB}}} ! \frac{\overline{\mathrm{AB}}}{\sqrt{\overline{\mathrm{OA}}^2\ \ \overline{\mathrm{AB}}^2}} \qquad (15)$$

(14)(15)

$$v ! c\frac{\sqrt{\overline{OA}^2 \quad \overline{AB}^2}}{\overline{AB}} \qquad (16)$$

$\overline{OA}$! 80 km $\overline{AB}$! 100 km

$$v ! 1.28c ! 3.8B10^8 \text{ m/s} \qquad (17)\ 4$$

[

a .8

O $t ! 0$

$t ! t_A$

A

A .

30kHz<<20MHz

.

$t ! t_B$ B

$\overline{AB} ! r$. a.

c

$$\overline{OA} ! ct_A \quad \overline{OB} ! c(t_A \quad t) \qquad (13)$$

t A B .

$$\overline{AB} ! \sqrt{\overline{OB}^2 \% \overline{OA}^2}$$

$$r ! \sqrt{c^2(t_A \quad t)^2 \% h^2} \qquad (14)\ 2$$

(14) t

$$v ! \frac{dr}{dt} ! \frac{c^2(t_A \quad t)}{\sqrt{c^2(t_A \quad t)^2 \% h^2}} ! c\frac{\overline{OB}}{\overline{AB}} ! \frac{c}{\cos :} \qquad (15)\ 2$$

$$\cos : ! \frac{\overline{AB}}{\overline{OB}} ! \frac{\overline{AB}}{\sqrt{\overline{OA}^2 \quad \overline{AB}^2}}$$

(15)

$$v ! c\frac{\sqrt{\overline{OA}^2 \quad \overline{AB}^2}}{\overline{AB}} \qquad (16)$$

$\overline{OA}$! 80 km $\overline{AB}$! 100 km

$$v ! 1.28c ! 3.8B10^8 \text{ m/s} \qquad (17)\ 4$$

]

5

$$m \quad g \quad {}_{He}V_0 g ! \ {}_1V_0 g \qquad (18)2$$

m $_1$ V_0

. (18)

$$V_0 ! \frac{m}{{}_1\% \ {}_{He}} \qquad (19)2$$

$_1$.

$$T = T_0 - Ez \qquad (20)2$$

$E = 5.0 \times 10^{-3}$ K/m .

$$\mathrm{d}p = - \quad g\,\mathrm{d}z \qquad (21)2$$

$$pV = \frac{m}{M}RT$$

$$= \frac{m}{V} = \frac{Mp}{RT} \qquad (22)$$

m V M R

. (22) (21)

$$\mathrm{d}p = -\frac{Mg}{RT}p\,\mathrm{d}z = -\frac{Mg}{R}\frac{p}{T_0 - Ez}\mathrm{d}z \qquad (23)2$$

(23)

$$\frac{\mathrm{d}p}{p} = -\frac{Mg}{R}\frac{\mathrm{d}z}{T_0 - Ez} = \frac{Mg}{ER}\frac{\mathrm{d}(T_0 - Ez)}{T_0 - Ez} \qquad (24)$$

$$\ln\left(\frac{p}{p_0}\right) = \frac{Mg}{ER}\ln\left(\frac{T_0 - Ez}{T_0}\right) \qquad (25)$$

$$p = p_0\left(1 - \frac{Ez}{T_0}\right)^{\frac{Mg}{ER}} \qquad (26)2$$

$$\frac{Mp_0}{RT}\ 1 \quad \frac{z}{T_0}^{\ \frac{Mg}{ER}} \qquad {}_0\frac{T_0}{T}\ 1 \quad \frac{z}{T_0}^{\ \frac{Mg}{ER}} \qquad {}_0\ 1 \quad \frac{z}{T_0}^{\ \frac{Mg}{ER}\ 1}$$