**МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ**
**имени М.В. ЛОМОНОСОВА**

# ОЛИМПИАДНАЯ РАБОТА

Наименование олимпиады школьников: **«Ломоносов»**

Профиль олимпиады: **Инженерные науки**

ФИО участника олимпиады: **Белецкий Максим Олегович**

Класс: **10**

Технический балл: **78**

Дата проведения: **01 марта 2022 года**

# РЕЗУЛЬТАТ ПРОВЕРКИ

| Задача 1 | Задача 2 | Задача 3 | Задача 4 | Всего |
|---|---|---|---|---|
| 24 | 20 | 25 | 9 | 78 |

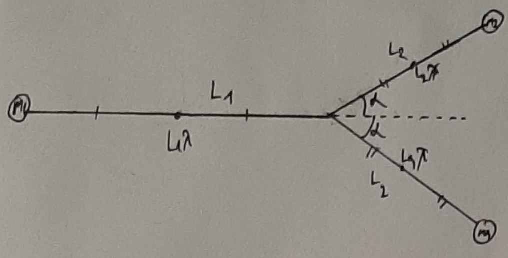
Чистовик 

# Задача № 1

Отсутствие горизонтальной нагрузки на ось означает, ~~что силы, обеспечивающие~~ ~~центрост~~ что центр масс карусели находится на оси вращения карусели.

Тогда:

$$L_1 m_1 + L_1\lambda \cdot \frac{L_1}{2} = L_2\cos(\alpha) m_2 + L_2\lambda\frac{L_2\cos(\alpha)}{2} + L_2\cos(\alpha) m_3 + L_2\lambda\frac{L_2\cos(\alpha)}{2} = 2\cos(\alpha)\left(L_2 m_2 + \frac{L_2^2\lambda}{2}\right)$$




$$\frac{L_1\left(m_1+\frac{\lambda L_1}{2}\right)}{2\cos(\alpha)} = \frac{\lambda}{2}L_2^2 + m_2 L_2$$

$$\frac{\lambda}{2}L_2^2 + m_2 L_2 - \frac{L_1\left(m_1+\frac{\lambda L_1}{2}\right)}{2\cos(\alpha)} = 0$$

$$L_2 = \frac{-m_2 + \sqrt{m_2^2 + 4\cdot\frac{\lambda}{2}\cdot\frac{L_1\left(m_1+\frac{\lambda L_1}{2}\right)}{2\cos(\alpha)}}}{\lambda} = \frac{-m_2 + \sqrt{m_2^2 + \lambda\cdot\frac{L_1\left(m_1+\frac{\lambda L_1}{2}\right)}{\cos(\alpha)}}}{\lambda}$$

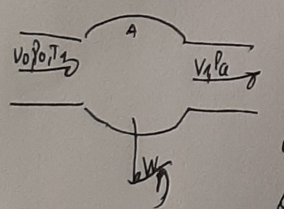
$$tg(\alpha) = \frac{3}{4} \Rightarrow \cos(\alpha) = \frac{4}{\sqrt{3^2+4^2}} = \frac{4}{5}$$

$$L_2 = \frac{-30 + \sqrt{30^2 + 20\cdot\frac{1(50+\frac{20}{2}\cdot 1)}{\frac{4}{5}}}}{20} = \frac{\sqrt{30^2+20\frac{5\cdot 60}{4}}}{20} - \frac{3}{2} = \frac{\sqrt{3^2+15}}{2} - \frac{3}{2} =$$

$$= \frac{\sqrt{24}}{2} - \frac{3}{2} = \sqrt{6} - \frac{3}{2} \approx 1{,}15 \text{ метра}$$

Ответ: $L_2$ должно быть равно $\left(\sqrt{6} - \frac{3}{2}\right)$ метра $\approx 1{,}15$ метра

# Задача № 2




$$\Delta Q = \Delta U + A$$

$$\Delta Q = -\frac{W}{\eta}$$

$$\Delta U = \frac{i}{2}\nu R_0 T_2$$

$$C_V = \frac{i}{2}R \Rightarrow \Delta U = C_V \nu \Delta T$$

$$\left.\begin{array}{l}\Delta T = T_2 - T_1 = \frac{V_1 P_a}{\nu R} - T_1 \\ \nu R = \frac{V_0 P_1}{T_1}\end{array}\right\} \Delta T = T_1\left(\frac{V_1 P_a}{V_0 P_1} - 1\right)$$

$$\nu = \frac{V_0 P_1}{R T_1} \Rightarrow \Delta U = C_V \frac{V_0 P_1}{R T_1} T_1\left(\frac{V_1 P_a}{V_0 P_1} - 1\right) = C_V \frac{V_1 P_a - V_0 P_1}{R}$$

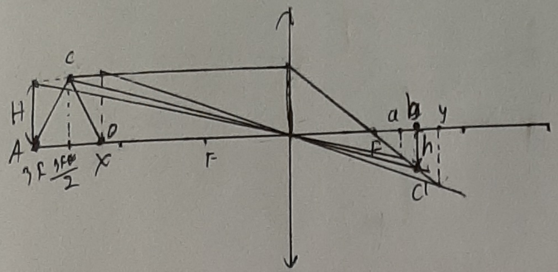
$$-\frac{W}{\eta} = C_V \frac{V_1 P_a - V_0 P_1}{R} + A \Rightarrow V_1 = V_0\frac{P_1}{P_a} - \frac{(\eta A + W)R}{\eta C_V P_a} = ~~22\cdot 10^7\cdot\frac{54000}{100} - (0{,}8\cdot 1{,}13\cdot 10^{11} +~~$$

$$= 22\cdot 10^7\cdot\frac{5400}{100} - \frac{(0{,}8\cdot 1{,}13\cdot 10^{11} + 275\cdot 10^{3}\cdot 3600)\cdot 8{,}314}{0{,}8\cdot 24{,}54\cdot 100\cdot 10^{7}} \approx 866{,}1\cdot 10^7 \text{ м}^3$$

Ответ: за час передастся $866{,}1\cdot 10^7$ м$^3$ метана

Чистовик

Задача №3




Из формулы тонкой линзы:

$$\frac{3F+x}{2H}=\frac{b}{h};\quad \frac{F}{H}=\frac{b-F}{h} \Rightarrow \frac{3F+x}{2h}=\frac{F}{b-F} \Rightarrow (3F+x)(b-F)=2bF \Rightarrow b=F\frac{3F+x}{F+x}$$

$$\frac{3F}{a}=\frac{F}{a-F} \Rightarrow 3aF-3F^2=aF \Rightarrow a=\frac{3F}{2}$$

$$\frac{x}{y}=\frac{F}{y-F} \Rightarrow xy=F(x+y) \Rightarrow y=\frac{xF}{x-F}$$

Из условия равенства площадей:

$$(3F-x)H=h(y-a)$$

$$\frac{3F-x}{y-a}=\frac{h}{H}=\frac{2b}{3F+x}$$

$$\frac{3F-x}{\frac{xF}{x-F}-\frac{3F}{2}}=\frac{2F\frac{3F+x}{F+x}}{3F+x}$$

$$\frac{2(3F-x)(x-F)}{3F^2-xF}=\frac{2F}{F+x}$$

$$\frac{2(x-F)}{F}=\frac{2F}{F+x}$$

$$2(x-F)(x+F)=2F^2$$

$$x^2-F^2=F^2$$

$$x^2=2F^2$$

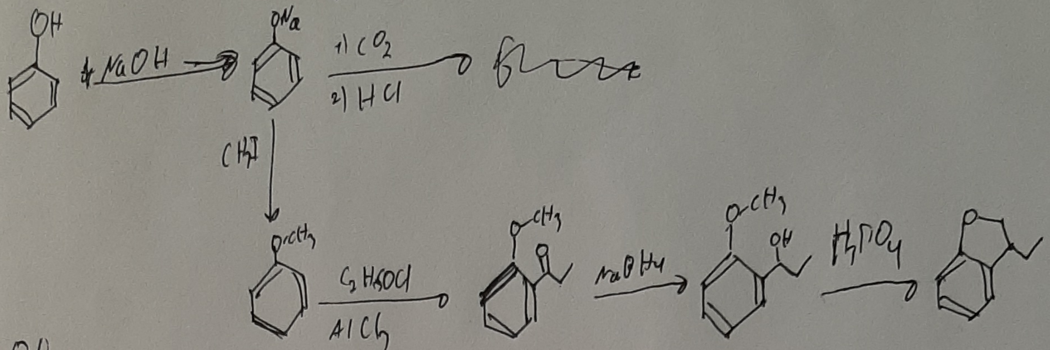
$$x=\sqrt{2}F$$

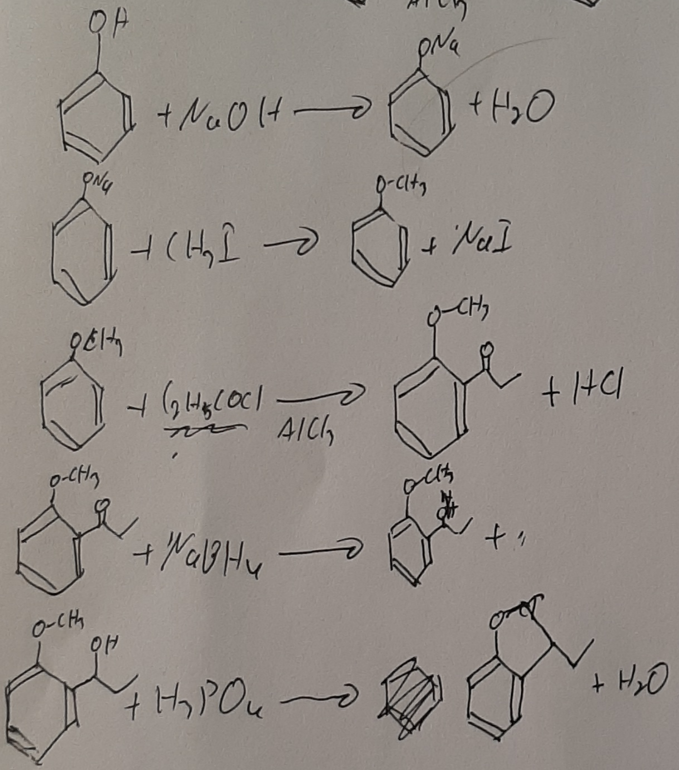
Основание ~~AB~~ ~~ΔABC равно~~ ~~Основание~~ $3F-x=(3-\sqrt{2})F\approx(3-\sqrt{2})\cdot 10$ см $\approx 15,86$ см

Ответ: $AB=(30-10\sqrt{2})\approx 15,86$ см

# Чистовик

## Задача №4



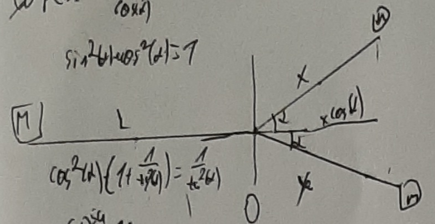


Черновик стр 1 

Лист 1

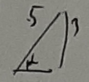
$\frac{2m\cos(\alpha)x + 2x\lambda\cos(\alpha)x}{2} = ML + \frac{L}{2}L\lambda$

$\sin^2(\alpha)+\cos^2(\alpha)=1$



$\cos^2(\alpha)\left(1+\frac{1}{\operatorname{tg}^2(\alpha)}\right)=\frac{1}{\operatorname{tg}^2(\alpha)}$

$\cos(\alpha) = \frac{4}{5} = 0{,}8$



$2\cdot 30\cdot\frac{4}{5}x + 2x^2\cdot 20\cdot\frac{4}{5} = 501 + \frac{1^2\cdot 20}{2}$

$ML + \frac{L^2\lambda}{2} = 2\left(mx\cos(\alpha) + \frac{x^2\lambda\cos(\alpha)}{2}\right)$

$48x + 16x^2 = 60$

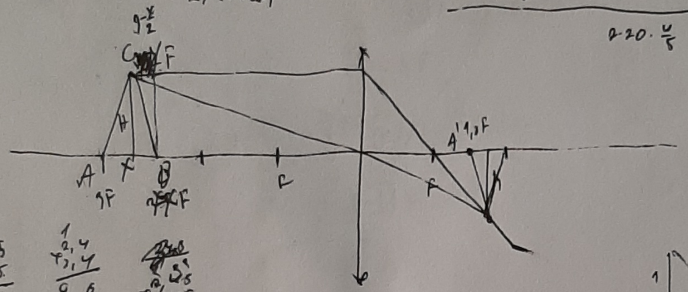
$2ML + L^2\lambda = 4mx\cos(\alpha) + 2x^2\lambda\cos(\alpha)$

$4x^2 + 12x + 15 = 0$

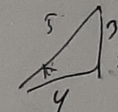
$x = \frac{-6 \pm \sqrt{6^2+60}}{4} = \frac{-6+\sqrt{96}}{4} = \frac{-6+4\sqrt{6}}{4} = \sqrt{6} - 1{,}5$

$x = \frac{-2m\cos(\alpha) + \sqrt{(2m\cos(\alpha))^2 + 2\lambda\cos(\alpha)\cdot(2ML+L^2\lambda)}}{2\lambda\cos(\alpha)}$

$= \frac{-2\cdot 30\cdot\frac{4}{5} + \sqrt{(2\cdot 30\cdot\frac{4}{5})^2 + 2\cdot 20\cdot\frac{4}{5}\cdot(2\cdot 501 + 1\cdot 20)}}{2\cdot 20\cdot\frac{4}{5}} = \frac{-48+\sqrt{48^2+32\cdot 120}}{32}$

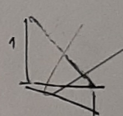


$\Rightarrow \cos(\alpha) = \frac{4}{5}$



$\frac{-12+\sqrt{12^2+8\cdot 30}}{8} = \frac{-3+\sqrt{3^2+15}}{2} = \frac{-3+\sqrt{24}}{2} = \sqrt{6} - \frac{3}{2}$

2,5 × 2,5 = 6,25 2,4 × 2,4 = 5,76 2,45 × 2,45 = 6,0025



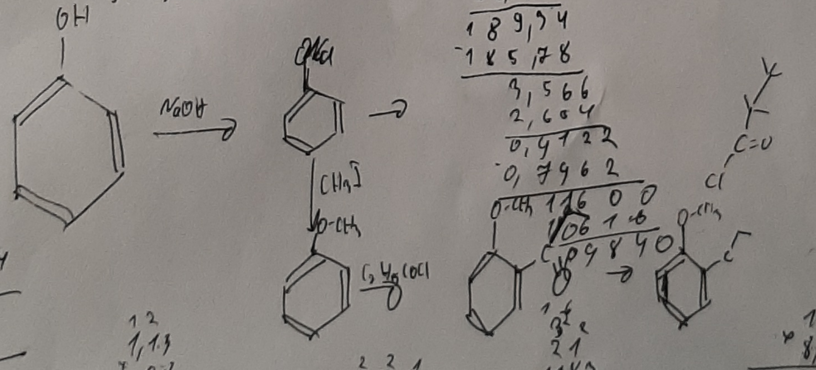
$\frac{1}{F} \quad \frac{1}{\frac{3+x}{2}F}$

$\frac{H}{\frac{3+x}{2}F} = \frac{2H}{(3+x)F} = \frac{h}{x'}$

$\frac{1}{F} - \frac{2}{\frac{3+x}{2}F} = \frac{3+x-2}{(3+x)F} = \frac{x+1}{(x+3)F}$

$S = Hx = hx'$

985,5462 | 26,54 ; 37,13



26,54 ; 53,08 ; 79,62 ; 106,16 ; 132,70 ; 159,24 ; 185,78 ; 212,32 ; 238,86 ; 265,40

54 × 22 = 1188

1,13 × 0,8 = 0,904 · $10^{-1}$

90,4 · $10^4$ + 77,9 · $10^4$

= 116,3 · $10^4$

4,47 × 775 × 28 = 27900

118,3 × 83,14 = 9835,462 · $10^9$

37,13 × 96 = 29,004 · $10^9$

28204

Черновик стр 2

лист 2

$$\frac{3F-\frac{x}{2}}{H}=\frac{F+b}{h}$$

$$\frac{h}{b}=\frac{F}{H}$$

$$\left(3F-\frac{x}{2}\right)h=(F+b)H$$

$$bH=hF$$

$$h=F(H+h)$$

$$\left(2F-\frac{x}{2}\right)h=HF$$

$$h=H\frac{F}{2F-\frac{x}{2}}$$

$$x'=x\frac{2F-\frac{x}{2}}{F}=|z-1{,}5F|$$

$$\frac{3F-x}{H}=\frac{F+z}{h}$$

$$\frac{h}{z}=\frac{H}{F}$$

$$\frac{h}{H}=\frac{F+z}{3F-x}=\frac{z}{F}$$

$$(F+z)F=z(3F-x)$$

$$F^2=z(2F-x)$$

$$z=\frac{F^2}{2F-x}$$

$$2x-\frac{x^2}{2F}=\frac{F^2}{2F-x}-\frac{3F}{2}=\frac{2F^2-3F(2F-x)}{4F-2x}=\frac{3Fx-4F^2}{4F-2x}$$

$$(4Fx-x^2)(4F-2x)=(3Fx-4F^2)2F$$

$$16F^2x-4Fx^2-8Fx^2+2x^3=6F^2x-8F^3$$

$$10F^2x-12Fx^2+2x^3=-8F^3$$

$$x^3-6Fx^2+5F^2x+4F^3=0$$

$$\Delta Q=\Delta U+A$$

$$-\frac{W}{\eta}=C_V\left(\frac{P_a V_x-P_0V_0}{R}\right)+A$$

Черновик ст. 7 — лист 8

$22 \cdot 54 = 1188$

$1{,}13 \cdot 0{,}8 = 0{,}904$

$26{,}54 \cdot 0{,}8 = 21{,}232$

$24{,}2 \cdot 24{,}2 = 585{,}64$

$1188 \cdot 10^3 - \frac{(0{,}904 \cdot 10^{11} + 2790 \cdot 10^9) \cdot 8{,}714}{21{,}232 \cdot 10^5}$

$3F - 1{,}761F = 1{,}239F$

$1188 \cdot 10^3 - \frac{10^9 (90{,}4 + 279)\cdot 8{,}714}{21{,}232 \cdot 10^5} = 10^3\left(1188 - \frac{831{,}9}{21{,}232} \cdot 8\right) = 10^3(1188 - 321{,}90) = 866{,}1 \cdot 10^3$

$831{,}9 : 2{,}553 = 321{,}90$

$\frac{y-a}{3F-x} = \frac{3F+x}{h} = \frac{F}{b-F}$

$\frac{\frac{xF}{x-F} - 3F}{3F-x} = \frac{y}{h'}$

$\frac{x}{F} = \frac{y}{7F}$

$xy - xF = yF$

$xy = F(x+y)$

$y(x-F) = xF$

$y = \frac{xF}{x-F}$

$\frac{2xF - 3F(x-F)}{(3F-x)(x-F)} = \frac{(3F+x)(F+x)}{F(3F+x)}$

$\frac{3F^2 - Fx}{2(3F-x)(x-F)} = \frac{(3F+x)(F+x)}{F}$

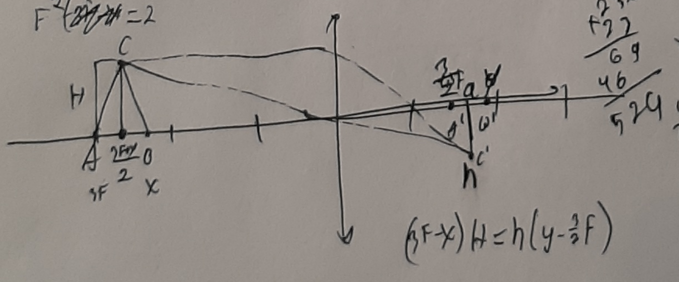
$F^2 = 2$

$(5x - 3F)(F-x) = 4F(3F+x)(x+F)$

$5x^2 + 2Fx - 3F^2 = -4x^2 + 16xF + 12F^2$

$9x^2 - 14xF - 15F^2 = 0$

$x = \frac{7F \pm \sqrt{49F^2 + 135F^2}}{9}$




$\frac{3F+y}{2} = F\frac{3F+x}{F+x}$

$(3F-x)H = h(y - 3F)$

$\frac{3F+x}{2H} = \frac{a}{h}$

$\frac{F}{H} = \frac{a-F}{h}$

$\frac{3F+x}{2a} = \frac{H}{h} = \frac{F}{a-F} = \frac{4\cdot 3F}{3F+x}$

$(3F+x)(a-F) = 2Fa$

$3Fa + xa - 3F^2 - xF = 2Fa$

$a(F+x) = F(3F+x)$

$a = F\frac{3F+x}{F+x}$

$\frac{3F + \frac{2xF}{x-F}}{4} = F\frac{3F-x}{F+x}$

$\frac{5Fx - 3F^2}{4(x-F)} = F\frac{3F-x}{F+x}$

$\frac{3F + \frac{2xF}{x-F}}{4} = F\frac{3F+x}{F+x}$

$\frac{3F(x-F) + 2xF}{4} = F\frac{3F+x}{F+x}$

$(xF - 3F^2)(F+x) = F \cdot 4 \cdot (3F+x)$

$(x - 3F)(F+x) = 4F(3F+x)$

Черновик стр 4 Лист 4

$$\frac{3F-x}{4-a} = \frac{3F+x}{2h}$$

$$\frac{3F-x}{\frac{xF}{x-F}-\frac{3F}{2}} = \frac{3F+x}{2F\frac{3F+x}{F+x}} = \frac{F+x}{2F}$$

$$\frac{(3F-x)2(x-F)}{2xF-3Fx+3F^2} = \frac{F+x}{2F}$$

$$\frac{(3F-x)2(x-F)}{3F^2-Fx} = \frac{F+x}{2F}$$

$$\frac{4(x-F)}{F} = \frac{F+x}{2F}$$

$$4(x-F) = F+x$$

$$3x = 3F$$

$$x = \frac{5}{3}F$$

$$\frac{3F-x}{4-a} = \frac{2h}{3F+x}$$

$$\frac{3F-x}{\frac{xF}{x-F}-\frac{3F}{2}} = \frac{2F\frac{3F+x}{F+x}}{3F+x} = \frac{2F}{F+x}$$

$$\frac{2(3F-x)(x-F)}{3F^2-xF} = \frac{2F}{F+x}$$

$$\frac{2(x-F)}{F} = \frac{2F}{F+x}$$

$$2x^2-2F^2 = 2F^2$$

$$2x^2 = 4F^2$$

$$x = \sqrt{2}F$$

1,76 × 1,76 = 1056 + 1232 + 176 = 3,0976

1,41 × 1,41 = 141 + 564 + 141 = 1,9881

1,42 × 1,42 = 284 + 568 + 142 = 2,0164

1,585

1,415 × 1,415 = 7075 + 1415 + 5660 + 1415 = 2,002225