ОРМО
Открытая региональная межвузовская олимпиада

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1 Two track and field athletes, Anton (A) and Boris (B), compete in running with a distance of s. Each of them followed their own tactics: Anton ran with constant acceleration for the first third of the way, ran with constant velocity V for the second third of the way, and slowed down with the same acceleration for the last third of the way. Boris ran at constant acceleration for the first third of the time, ran at constant speed V for the second third of the time (the same as Anton's), and slowed down for the last third of the time with the same acceleration as the start. Which of the athletes will finish first? By what time Δt will he overtake his opponent?

Analysis of Anton's Motion: Anton divides the total distance (s) into three equal segments

First $\frac{s}{3}$: starts from rest ($u=0$) with constant acceleration (a)

Using $V^2 = 2a\cdot\frac{s}{3}$

find $a = \frac{3V^2}{2s}$

The time for this phace is $t_{A1} = \frac{V}{a} = \frac{2s}{3V}$

Middle $\frac{s}{3}$: Runs at speed (V)

Time: $t_{A2} = \frac{s}{3V}$

Final $\frac{s}{3}$: Deceleration — a to rest

Time: $t_{A3} = \frac{2s}{3V}$

Total time for Anton: $T_A = t_{A1} + t_{A2} + t_{A3} = \frac{2s}{3V} + \frac{s}{3V} + \frac{2s}{3V} = \frac{5s}{3V}$

Analysis of Boris's Motion: Boris divides the total time T_B into three equal intervals

First $\frac{T_B}{3}$: constant acceleration a to reach speed V.

Beause $V = a\cdot\frac{T_B}{3}$ We get $a = \frac{3V}{T_B}$

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Distance covered : $S_{B1} = \frac{1}{2} a \left(\frac{T_B}{3}\right)^2 = \frac{VT_B}{6}$

Middle $\frac{T_B}{3}$: Constant velocity V.

Distance covered: $S_{B2} = \frac{VT_B}{3}$

Final $\frac{T_B}{3}$: Deceleration $-a$ to rest

Distance covered : $S_{B3} = \frac{VT_B}{6}$

Total Distance : $S = S_{B1} + S_{B2} + S_{B3} = \frac{VT_B}{6} + \frac{VT_B}{3} + \frac{VT_B}{6} = \frac{2VT_B}{3}$

solving for T_B: $T_B = \frac{3S}{2V}$

comparison and time Difference:

Anton's Total time : $T_A = \frac{5S}{3V}$

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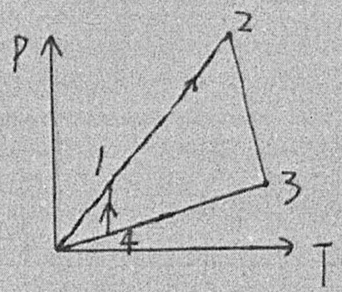
2. Two juggles simultaneously throw balls to each other with the same initial velocity V_0, but at different angles to the horizon. Determine the minimum distance between the balls during the flight. The distance between the jugglers is S. Balls are thrown and caught at the same height. Ignore the air resistance.

Equations of Motion:
Ball 1 (thrown from (X = 0) $X_1(t) = V_0 \cos\theta_1 \cdot t$ $\quad Y_1(t) = V_0 \sin\theta_1 \cdot t - \frac{1}{2}gt^2$
Ball 2 (thrown from (X = S) $X_2(t) = S - V_0 \cos\theta_2 \cdot t$ $\quad Y_2(t) = V_0 \sin\theta_2 \cdot t - \frac{1}{2}gt^2$
Distance Formula
The squared distance between the balls at time (t)
$D^2(t) = [S - V_0 t(\cos\theta_1 + \cos\theta_2)]^2 + [V_0 t(\sin\theta_2 - \sin\theta_1)]^2.$
Critical Time for Minimum Distance
By differentiating $D^2(t)$ and setting the derivative to zero, the critical time (t) is:
$t = \frac{S(\cos\theta_1 + \cos\theta_2)}{V_0[(\cos\theta_1 + \cos\theta_2)^2 + (\sin\theta_2 - \sin\theta_1)^2]}$
Minimum Distance Expression:
Substituting (t) into $D^2(t)$ and simplifying, we obtain the squared minimum distance:
$D^2_{min} = S^2 \cdot \frac{(\sin\theta_2 - \sin\theta_1)^2}{(\cos\theta_1 + \cos\theta_2)^2 + (\sin\theta_2 - \sin\theta_1)^2}$
We further simplify to:
$D_{min} = S \cdot \left|\sin\left(\frac{\theta_1 - \theta_2}{2}\right)\right|$
Conclusion:
The minimum distance between the balls during their flight is:
$D_{min} = S \cdot \left|\sin\left(\frac{\theta_1 - \theta_2}{2}\right)\right|$

0б

3. The figure shows a gragh of a cyclic process occurring witha certain amount of an ideal monatomic gas. Use the graph to determine the efficiency of the heat engine operating on this cycle. Give the answer as a percentage in the form of an integer



Heat Engine Efficiency

$C_V=\frac{3}{2}R \quad C_P=\frac{5}{2}R$

$Q_1=nRT_1\ln\frac{V_2}{V_1} \quad \Delta V=0$

$Q_2=nC_P\Delta T$

$Q_3=nC_V\Delta T$

Conclusion: The heat engine efficiency is 20%. 65

4. Express changes in Terms of Potentials:

The potential at a distance d from a charge q is $\phi = k\frac{q}{d}$

$q_1 = \frac{\phi d}{k}$ $q_2 = \frac{\phi_2 d}{k}$ $q_3 = \frac{\phi_3 d}{k}$.

ball 1 Forces:

Coulomb's law: $F_{12} = k\frac{q_1 q_2}{d^2} = \frac{\phi_1\phi_2}{k}$ $F_{13} = \frac{\phi_1\phi_3}{k}$

Vector Addition of Forces:

Angle between forces $60°$

$F_1 = \sqrt{F_{12}^2 + F_{13}^2 + 2F_{12}F_{13}\cos(60°)}$

We further simplify to:

$F_1 = \frac{\phi_1}{k}\sqrt{\phi_2^2 + \phi_3^2 + \phi_2\phi_3}$

5. First $T = 43.30°C + 273.15°C = 316.45K$

Calculate partial pressures of water vapor (10% - 90%)

initial humidity $P_1 = 0.1 \times 9000 = 900pa$ (water)

New humidity $P_2 = 0.9 \times 9000 = 8100pa$ (water)

initial $P_1 = 10000pa - 900pa = 99100pa$ (dry air)

new $P_2 = 10000pa - 8100pa = 91900pa$ (dry air)

For inital humidity (10%)

$$P_{d1} = \frac{99100 \times 0.02897}{8.314 \times 316.45} \approx 1.0913 kg/m^3$$

$$P_{w1} = \frac{900 \times 0.018015}{8.314 \times 316.45} \approx 0.00616 kg/m^3$$

$$P_{air1} = 1.0913 + 0.00616 = 1.0975 kg/m^3$$

For new humidity (90%)

$$P_{d2} = \frac{91900 \times 0.02897}{8.314 \times 316.45} \approx 1.0119 kg/m^3$$

$$P_{w2} = \frac{8100 \times 0.018015}{8.314 \times 316.45} \approx 0.5545 kg/m^3$$

$$P_{air2} = 1.0119 kg/m^3 + 0.5545 kg/m^3 = 1.06735 kg/m^3$$

inital $1.0985 kg/m^3 \times 5000m^3 \times 9.81 m/s^2 \approx 53906N$

New $1.06735 kg/m^3 \times 5000 m^3 \times 9.81 m/s^2 \approx 52495N.$

Diffence : $53906 - 52495 = 1447N$

Mass to drop $\frac{1447N}{9.81 m/s^2} \approx 147.5kg$

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Difference in air density: $0.03 kg/m^3$

Mass difference $0.03 kg/m^3 \times 5000 m^3 = 150 kg$

So. the weight of the ballast that is 150kg.

10б

вложность