Kinematics 2D - Opgaver

10060
Physics

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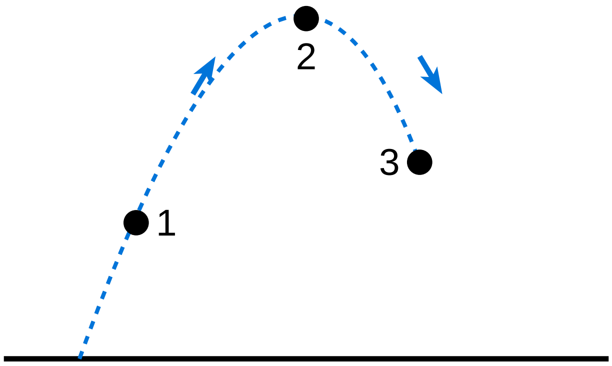
Rasmus Rosendahl-Kaa

Chapter 4 - Problems
Physics

Problem 1

A particle moves in a projectile motion neglecting air resistance. In the figure below, part of the parabolic trajectory is drawn, and three points, 1, 2 and 3, are marked. The speed of the particle in the points are v_1, v_2 and v_3.



What is the relationship between the speed in the three points?

A) $v_1 = v_2 = v_3$

B) $v_1 < v_2 < v_3$

C) $v_1 < v_3 < v_2$

D) $v_2 < v_1 < v_3$

E) $v_2 < v_3 < v_1$

F) $v_3 < v_1 < v_2$

G) $v_3 < v_1 < v_2$

H) Don't know

Solution:

E)

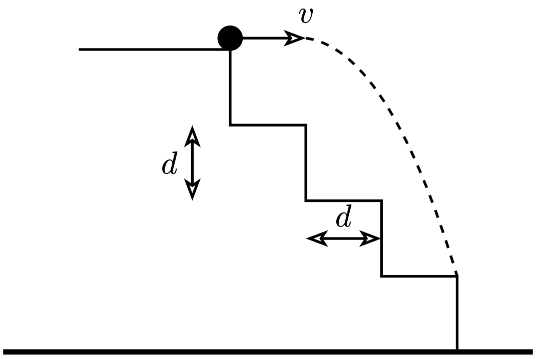
Da der ingen luftmodstand er kan vi se bort fra den da den må være ens i alle punkter.

v_2 er mindst fordi der står den stille lodret.

v_3 er mindre end v_1 fordi den er højere oppe. Den tid/afstand det tager for en hastighed at blive 0 mod konstant acceleration, må hastigheden være den samme i modsat retning samme sted men på vej ned.

Problem 2

A person kicks a ball which rests on the top of a staircase. The ball has a horizontal velocity v after the kick. The ball just misses the lowest step on the staircase. Each step on the staircase is a square with side lengths d.



What is the magnitude of the initial velocity v?

A) $v = \frac{\sqrt{gd}}{2}$ B) $v = \sqrt{gd}$ C) $v = \sqrt{3gd}$
D) $v = 3\sqrt{gd}$ E) $v = \frac{\sqrt{3gd}}{\sqrt{2}}$ F) $v = \frac{\sqrt{3gd}}{2}$
G) $v = \frac{3\sqrt{gd}}{\sqrt{2}}$ H) $v = \frac{\sqrt{3gd}}{4}$ I) Don't know

Solution:

Vi ved: $3d = v \cdot t$

Da den må have bevæget sig lige langt i x- og y-retning til sidst, må v være gennemsnitshastigheden, bolden bevæger sig i, i y-retningen, aka $\frac{v_{\text{slut}}}{2}$:

$$\begin{aligned} v_{\text{slut}}^2 &= 0 + 2 \cdot g(3d) \\ v_{\text{slut}}^2 &= 2 \cdot 3gd \\ v_{\text{slut}} &= \sqrt{6gd} \end{aligned} \tag{1}$$

Svar er **C) forkert**

Problem 3

A person is at equator and is moving in a circular motion. The radius of the earth is 6370 km.

a) Determine the acceleration of the person.

If earth were rotating faster, the person would become weightless when the acceleration was g.

b) Determine the period of rotation of the earth if a person had to become weightless.

Solution:

a)

It takes 24 hours for person to make one rotation

$$a_{\text{rad}} = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 \cdot 6370km}{(24h)^2} \approx 0,0337\frac{m}{s^2} \tag{2}$$

b)

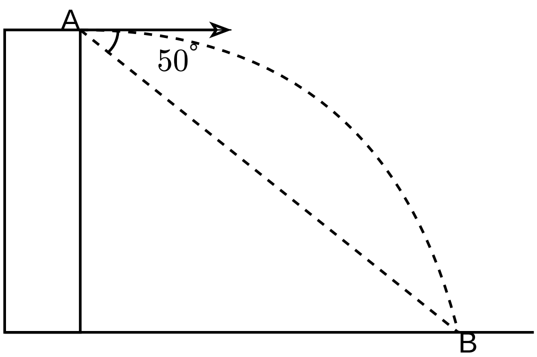
Now we have the a_{rad} so use same formular as before, but isolate for T

$$\begin{aligned} 9.82\frac{m}{s^2} &= \frac{4\pi^2 6370km}{T^2} \Leftrightarrow \\ T^2 &= \frac{4\pi^2 6370km}{9.82\frac{m}{s^2}} \\ T^2 &= \frac{4\pi^2 \cdot (6370 \cdot 10^3)m}{9.82\frac{m}{s^2}} \\ T &= \sqrt{\frac{4\pi^2 \cdot (6370 \cdot 10^3)m}{9.82\frac{m}{s^2}}} \approx 5060s \end{aligned} \tag{3}$$

5060 seconds is about 1 hour and 24 minutes or 1.4 hours

Problem 4

A rock is thrown from a point A on top of a tower and hits the point B on the ground 3.5 s later. The line from A to B has an angle of 50° with the horizon.



a) Determine the initial speed of the rock.

Solution:

Start height: $\frac{1}{2} \cdot 9.82 \cdot 3.5^2 = 60.1475m$

Calculate distance to B:

$$\begin{aligned} \tan(40^{\circ}) &= \frac{B}{60.1475} \\ B &= \tan(40^{\circ}) \cdot 60.1475 \approx 50.47m \end{aligned} \tag{4}$$

Hastighed må være $\frac{B}{t} = \frac{50.47}{3.5} = 14.42\frac{m}{s}$

Problem 5

A person plays with a tennis ball in a large room and tries to throw the ball from one end of the room and hit a picture hanging $h = 30$ cm from the ceiling on the opposite end of the room. It is assumed, that the person throwing the ball, throws the ball in the same height as the picture. The ball just barely avoids touching the ceiling. The room is $L = 10$ m long.

a) Determine the initial speed of the ball, the initial angle and duration of flight if the ball has to hit the picture.

Solution:

We know the following things:

$$\begin{aligned} v_y(t^*) &= 0 \\ y(t^*) &= 30cm \\ x\left(\frac{T}{2}\right) &= 5m \end{aligned} \tag{5}$$

To get initial angle:

$$\begin{aligned} \theta &= \arctan\left(\frac{2 \cdot 2 \cdot h}{L}\right) \\ &= \arctan\left(\frac{2 \cdot 2 \cdot 30}{10 \cdot 100}\right) = \frac{3}{25} \text{ rad} = 6.875^\circ \end{aligned} \tag{6}$$

Initial speed:

$$v_0 = \sqrt{\frac{h \cdot 2g}{\sin^2}(\theta)} = \sqrt{\frac{0.3m \cdot 2 \cdot 9.82\frac{m}{s^2}}{\sin^2}\left(\frac{3}{25}\right)} \approx 20.28\frac{m}{s} \approx 73\frac{\text{km}}{t} \tag{7}$$

Time:

$$T_{\text{tot}} = \frac{2 \cdot v_0 \cdot \sin(\theta)}{g} = \frac{2 \cdot 20.28 \cdot \sin(\frac{3}{25})}{9.82} \approx 0.5s \tag{8}$$

Problem 6

A diver jumps from 3 m springboard. During the jump, the diver reaches a height on 2.5 m above the springboard and lands in the water 2.8 meters from the starting point.

a) Determine the x and y components of the initial speed, the angle of the jump as well as the duration of flight.

Solution:

Initial y-speed:

$$\begin{aligned} t &= -\frac{v_0}{-g} = \frac{v_0}{g} \\ 2.5m &= v_0 \cdot \frac{v_0}{g} + \frac{1}{2}g\left(\frac{v_0}{g}\right)^2 \\ &= \frac{v_0^2}{g} + \frac{1}{2}g\frac{v_0^2}{g^2} \\ &= \frac{v_0^2}{g} + \frac{1}{2}\frac{v_0^2}{g} \\ &= \frac{3v_0^2}{2g} \\ 3v_0^2 &= 2.5m \cdot 2g \\ v_0 &\approx 7\frac{m}{s} \end{aligned} \tag{9}$$

Total time:

$$\begin{aligned} 0 = 3m + 7\frac{m}{s} \cdot ts - \frac{1}{2} \cdot 9.82\frac{m}{s^2} \cdot t^2 \\ t \approx 1.77s \end{aligned} \tag{10}$$

Inital x-speed:

$$\begin{aligned} 2.8m &= v_{0x} \cdot 1.77 \\ v_{0x} &= \frac{2.8}{1.77} \approx 1.58\frac{m}{s} \end{aligned} \tag{11}$$

Angle:

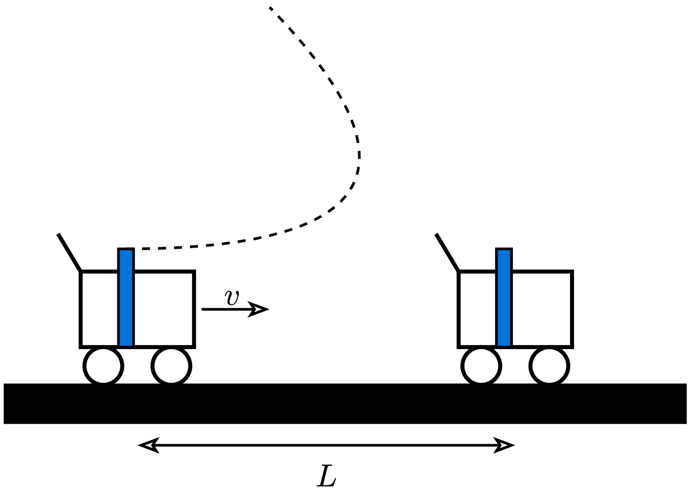
To find angle, we can use trigonometry. We can make the triangle for when the diver reaches top height after $\frac{7}{9.82}$ seconds.

Height is 2.5, length is $1.58 \cdot \frac{7}{9.82} \approx 1.13m$

Angle must be $\arctan\left(\frac{2.5}{1.13}\right) \approx 1.147 \text{ rad} \approx 65.72^{\text{deg}}$

Problem 7

In a shopping cart a vertical toy cannon is placed. The shopping cart is traveling with constant speed v on the floor in the supermarket. The cannon shots by mistake a projectile vertical into the air compared to the shopping cart, with the same velocity v as the shopping cart is traveling with. By accident, the projectile from the cannon end up into the cannon after the shopping cart has traveled the distance L.



What is the velocity v which makes this maneuver possible?

A) $v = \sqrt{gL}$

B) $v = \sqrt{2gL}$

C) $v = \sqrt{2\sqrt{2}gL}$

D) $v = \sqrt{\frac{gL}{2}}$

E) $v = \sqrt{\frac{gL}{2\sqrt{2}}}$

F) Don't know

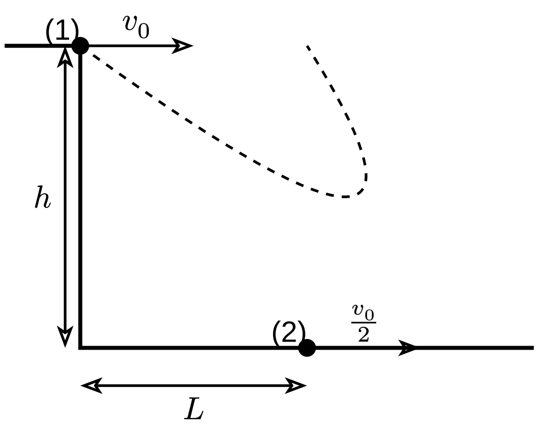
Problem 8

A ball is thrown from one person to another, with a distance L between one another. The ball is thrown and catched at the same height. The ball is thrown in a way, so the ball is at the receiver with lowest speed possible.

a) What is the speed of the ball immediately before it is catched? b) At what angle should the ball be thrown?

Problem 9

A particle (1) is at time $t = 0$ thrown with an initial velocity v_0 from an unknown height h above the ground. At the same time, another particle (2) with initial velocity is thrown along the ground. Particle (2) starts its horizontal movement at point L to the right of the first particle. Neglect any friction. At an unknown time T, the two particles collide.



a) Determine the time T. b) Determine the height h.

The height is assumed known: c) What is the magnitude of the relative speed, $[v]_{rel} = [v]_1 - [v]_2$ between the two particles immediately before they collide?

Problem 10

A football player has a free kick $3L = 30.0$ m from the goal. The wall of defenders is placed 10.0 m from where the free kick is taken. The wall of defenders is $h = 2.0$ m tall. The goal has the height $H = 2.44$ m. The football player kicks the ball, so the initial velocity has an angle of 15° with the horizon, and he kicks it hard enough, so the ball does not hit the ground before it hits the goal.

a) Make a drawing of the situation with relevant physical magnitudes. b) Determine the initial velocity the football player has to kick the ball, so the ball just barely goes over the wall. c) Determine the interval of initial speed in which the ball ends in the goal.

Problem 11

A car travels in on a circular track with radius R. The car starts from rest and has a tangential acceleration a_0.

a) Derive an expression for the speed of the car and the radial acceleration. b) Determine the magnitude of the acceleration of the car when it has traveled one round on the track.