PHYSIKSOLYMPIAD
LËTZEBUERG 2019

Qualification (EN)

10.1.2019

Formulae

Kinematics (UAM)

$x = \frac{1}{2}at^2 + v_0 t + x_0$

$v = at + v_0$

$v^2 - v_0^2 = 2a(x - x_0)$

Forces

$F = ma$

$F_f \leq \mu N$

Work, Energy, Power

$W = Fd\cos\theta$

$E_{cin} = \frac{1}{2}mv^2$

$E_{pes} = mgh$

$E_{el} = \frac{1}{2}kx^2$

$P = \frac{W}{t} = Fv$

Momentum

$p = mv$

$F = \frac{\Delta p}{\Delta t}$

Thermal concepts

$Q = mc\Delta\theta$

$Q = mL$

Ideal gas laws

$p = \frac{F}{A}$

$pV = nRT = Nk_BT$

$E_K = \frac{3}{2}k_BT$

Oscillations and waves

$T = \frac{1}{f}$

$c = f\lambda$

$T = 2\pi\sqrt{\frac{l}{g}}$

$T = 2\pi\sqrt{\frac{m}{k}}$

Electricity

$I = \frac{Q}{t}$

$F = k \cdot \frac{q_1 q_2}{r_2}$

$V = \frac{W}{q}$

$E = \frac{F}{q}$

$V = RI$

$P = VI = RI^2 = \frac{V^2}{R}$

$R = R_1 + R_2 + \cdots + R_n$

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$

$\rho = \frac{RA}{L}$

Electro-magnetism

$F = qvB\sin\theta$

$F = BIL\sin\theta$

Circular motion

$v = \omega r$

$a = \frac{v^2}{r}$

Gravitation

$F = G\frac{mM}{r^2}$

$g = \frac{F}{m}$

Quantum physics

$E = hf$

$\lambda = \frac{hc}{E}$

Optics

$n_1 \sin\alpha_1 = n_2 \sin\alpha_2$

$\frac{1}{q} + \frac{1}{p} = \frac{1}{f}$

1. An incompressible liquid (constant density) flows in a pipe of diameter d with a speed v. If the pipe narrows gradually to half its original diameter, identify the correct final speed of the liquid.

    a. $v_F = v$
    b. $v_F = v/2$
    c. $v_F = 2v$
    d. $\boldsymbol{v_F = 4v}$

2. A hot air balloon descends vertically with a speed of 11 m / s. The pilot drops a bag of sand that reaches the ground in 7 s. How far did the bag fall, neglecting air resistance?

    a. 168 m
    b. 245 m
    c. 322 m
    d. 528 m

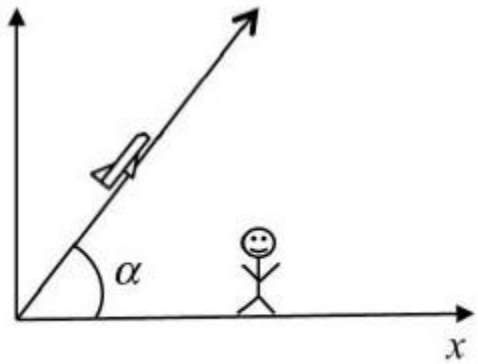
3. A small hollow boat floats in a bathtub. If you use a spoon to move water from the tub into the boat, what happens with the water level in the tub?
    a. The water level drops.
    b. The water level is rising.
    c. The water level remains constant.
    d. There is not enough information to conclude.

4. A car accelerates uniformly from $0\ m/s$ to $20\ m/s$ over a distance d in a time t. Another car takes twice as long to reach the same final speed. What is the distance travelled by the second car?
    a. $\frac{d}{4}$
    b. $\frac{d}{2}$
    c. $\boldsymbol{2d}$
    d. $4d$

5. A metal cube has side length x. The electrical resistance between 2 opposite sides of the cube is:
    a. Proportional to x
    b. Proportional to x^2
    c. Inversely proportional to $\boldsymbol{x}$
    d. Independant of x

6. A pool is 5 m wide and 10 m long and is filled to a height of 3 m. The force exerted by the water on the side wall of the width can be estimated at:
    a. $0\ N$
    b. $3 \cdot 10^3\ N$
    c. $\boldsymbol{10^5\ N}$
    d. $2 \cdot 10^7\ N$

7. A jet having a constant speed *v* rises at an angle α = 60 to the ground. An observer perceives the shock wave from the take off when the jet is vertically overhead. What is the speed of the jet? We will take u = 340 m / s for the speed of sound.



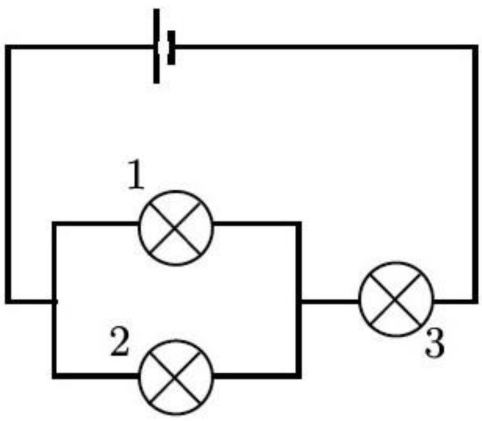
a. $v = 481\frac{m}{s}$
b. $v = 240\frac{m}{s}$
c. $v = 1200\frac{m}{s}$
d. $\boldsymbol{v = 680\frac{m}{s}}$

8. Consider a planet of radius R = 24273 km and density ρ = 1660 kg/m^3. What is the minimum satellite speed required in order to put the satellite into orbit?
   a. $4{,}7\frac{km}{s}$
   b. $3.9 \cdot 10^{-19}\frac{m}{s}$
   c. $14{,}08\frac{m}{s}$
   d. $\boldsymbol{16{,}5\frac{km}{s}}$

9. What is the rotation period of Mars around the Sun? The following quantities are known:

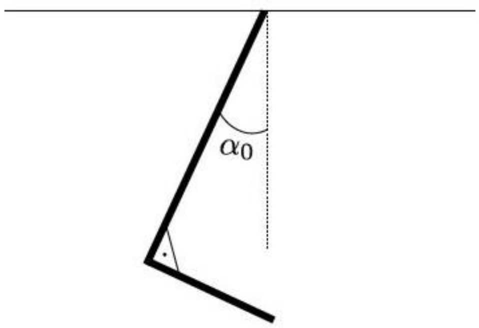
   Earth-Sun distance: $1.50\cdot10^{11}$ m
   Mass of the Earth: $5.97\cdot10^{24}$ kg
   Minimum distance Earth-Mars: $7.83\cdot10^{10}$ m
   Mass of Mars: $6.42\cdot10^{23}$kg
   Temperature on the surface of the Sun: 5800 K
   a. $2{,}4 \cdot 10^{7}\ s$
   b. **$9{,}8\cdot10^{5}$ minutes**
   c. 4665 hours
   a. 483 days

10. Consider a simple circuit consisting of three lamps. The first two are connected together in parallel, and the third is connected in series with the block formed by the first two lamps. If the first lamp breaks down, what happens with the other two?



a. They both become brighter.
b. Nothing happens to the third, but the second becomes brighter.
c. Nothing happens to the second, but the third becomes brighter.
d. The second becomes brighter, but the third becomes dimmer.

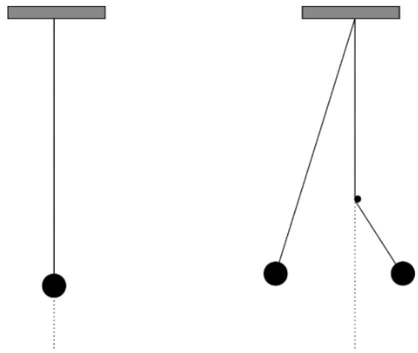
11. Consider two cylindrical rods of diameter 2 cm, and lengths 1 m and respectively 2 m. They are fixed together in a right-angled to form a rigid "L". The end of the long rod is then attached so that this "L" can freely rotate in a vertical plane. We now position this "L" with an angle α_0 between the vertical and the long stick.



By releasing the "L", it starts oscillating, unless it is released from a specific angle. What is the value of α_0 for this position?

a. 0°
b. 7°
c. 14°
d. 21°

12. A simple pendulum is attached to a support. It consists of a string of length L and negligible mass and a mass m attached to its free end. It hangs vertically as shown below. It is displaced 5 degrees from the vertical and released. It then undergoes oscillations back and forth. During its oscillation, it hits a peg located at 2/3 of the length from the fixed end, as indicated in the diagram below. What is the time period of one oscillation?



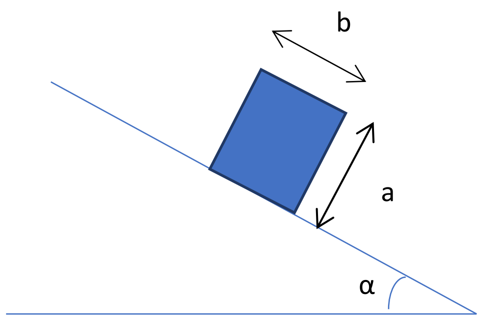
a. $\pi\sqrt{\frac{L}{g}}\left(1+\sqrt{\frac{2}{3}}\right)$

b. $\boldsymbol{\pi\sqrt{\frac{L}{g}}\left(1+\sqrt{\frac{1}{3}}\right)}$

c. $\pi\sqrt{\frac{L}{g}}\left(1+\frac{1}{3}\right)$

d. $\pi\sqrt{\frac{L}{g}}\left(2+\frac{2}{\sqrt{3}}\right)$

13. A homogeneous block of mass m, length b and height a is placed on an inclined plane of angle α with respect to the horizontal as indicated below. The coefficient of static friction between the block and the inclined plane is μ_S. The plane is inclined from the horizontal to an angle α. For a given angle the block will either slide along the plane or tip over. What condition must be met for the block to tip over without slipping.



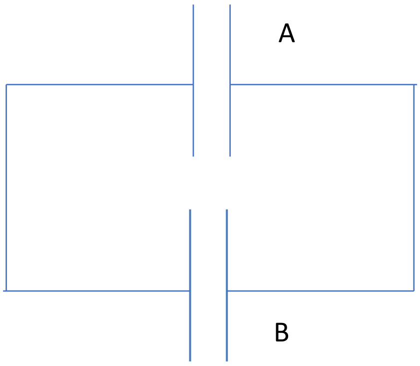
a. $\mu_S > \frac{a}{b}$

b. $\boldsymbol{\mu_S > \frac{b}{a}}$

c. $\mu_S > 1 - \frac{b}{a}$

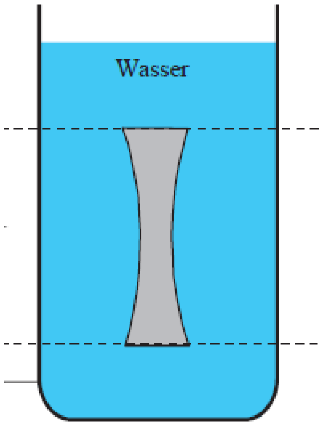
d. $\mu_S < \frac{b}{a}$

14. A first capacitor A of capacity C is connected to a voltage source to charge it. When the voltage at its terminals is equal to V the charge on it is equal to Q. It is then disconnected from the voltage source. Then a second capacitor B of capacitance 2C is connected in parallel to the first one as shown below. The charge carried by the capacitors A and B respectively after a certain time will be equal to



a. $Q_A = Q$ and $Q_B = 2 \cdot Q$
b. $Q_A = \frac{Q}{2}$ and $Q_B = \frac{Q}{2}$
c. $Q_A = \frac{Q}{3}$ and $Q_B = \frac{2}{3}Q$
d. $Q_A = \frac{2Q}{3}$ and $Q_B = \frac{Q}{3}$

15. A lens of refractive index n_{lens} of the form shown below is placed in water (refractive index n_{water}). Under what condition will it work as a divergent lens in air and as a convergent lens in water?



a. $n_{lens} > n_{water} > n_{air}$
b. $n_{air} < n_{lens} < n_{water}$
c. $n_{lens} > n_{air} > n_{water}$
d. $n_{lens} < n_{air} < n_{water}$

16. A train travels at speed $v_1$without friction on horizontal rails. A wagon on the train is open at the top and the area of the opening is "A". It rains homogeneously and the drops fall vertically with a constant speed v_2. The precipitation rate is assumed to be constant, for example 1mm / min. Let m be the mass of water collected in one hour. Identify the correct statement:
    a. if $v_1 \uparrow$ then $m \downarrow$
    b. then $v_2 \uparrow$ then $m \uparrow$
    c. if $A \uparrow$ then $m \downarrow$
    d. **m is independent of v_1 and v_2**

17. An electric dipole is composed of two charges q and -q which are at a fixed distance d from one another. When this dipole is placed in a uniform electric field E perpendicular to the axis of the dipole, it feels a moment $\boldsymbol{M}$ around its center, where $\boldsymbol{M\ is}$:
    a. $\boldsymbol{M = qEd}$
    b. $M = \frac{qE}{d}$
    c. $M = 2qEd$
    d. $M = \frac{qEd}{2}$

18. A movable magnetic needle is placed between the poles in the air gap of a U-shaped magnet, in which region there is a uniform magnetic field. Identify the incorrect statement.
    a. The needle is oriented along the field lines.
    b. The needle experiences a rotation.
    c. The needle is drawn to the North Pole of the magnet.
    d. The needle indicates the direction of the magnetic field.

19. In order to detect planets in distant solar systems, we measure the luminosity (luminous power) of the stars as a function of time and when the orbit of the planet is in the direction of observation, the planet of radius r passes in front of the star, decreasing the brightness of the light received. This decrease in brightness is:

a. Proportional to the radius of the planet
b. Proportional to the square of the radius of the planet
c. Proportional to the cube of the radius of the planet
d. Independent of the size of the planet

20. A proton and a helium nucleus are accelerated by the same potential difference. The ratio of kinetic energies: $\frac{E_k(\text{helium})}{E_k(\text{proton})}$ is:

a. 1
b. √2
c. 2
d. 4