Test in Physics

Every correctly circled reply with detailed procedure and adequate explanation is marked with 5 points. For incorrectly circled reply procedure is not considered.

1. A particle M attached to the end of a light string moves along the frictionless horizontal surface (Figure 1). The other end of the string is partially wrapped around a motionless cylinder whose axis is perpendicular to the surface. The particle is moving with constant speed v_0 and the velocity vector is always perpendicular to the string direction. The string is tightened during the particle motion and it wounds around the cylinder. If the initial length of the unwound string is L the time τ required for the string to become completely wrapped around the cylinder is:

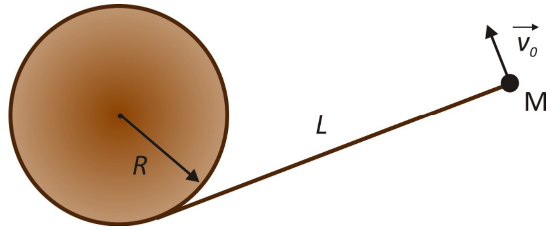

Figure 1

a) $\tau = \frac{L}{v_0}$

b) $\tau = \frac{L}{v_0}\left(\sqrt{1+\frac{L^2}{2R^2}}-1\right)$

c) $\tau = \frac{L^2}{2v_0 R}$

d) $\tau = \frac{L}{v_0}\left(\sqrt{1+\frac{L^2}{2R^2}}+1\right)$

e) None of the offered answers

2. A half of the disc with uniform mass density is supported by two strings (Figure 2). If the weight of the suspended object is Q the tensions S_1 and S_2 in the strings are:

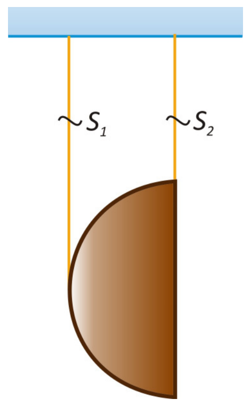

Figure 2

a) $S_1 = 0.42Q; \quad S_2 = 0.58Q$

b) $S_1 = S_2 = 0.5Q$

c) $S_1 = 0.25Q; \quad S_2 = 0.75Q$

d) $S_1 = 0.37Q; \quad S_2 = 0.63Q$

e) None of the offered answers

3. A climber descends from the top of a cliff by pining up a pulley to the top of the cliff. He passes a rope over the pulley and ties one end of the rope around his waist. The other end of the rope he holds in his hands and descends slowly. If the climbers mass is m_A = 80 kg, and the rope breaks when the tension is S_{max} =500 N, can the climber descend safely in this way? If he decides to climb up the cliff in the same way what is the maximum acceleration a_{max} with which he can rise?

a) Yes, $a_{\max} = 3.56\, m/s^2$

b) No, $a_{\max} = 0.73\, m/s^2$

c) No, and he can't climb up either

d) Yes, $a_{\max} = 2.69\, m/s^2$

e) None of the offered answers

4. A particle of mass *m* is moving along the horizontal direction with speed *v* when it collides with a particle of mass *2m* initially at rest (Figure 3a). After the collision the first particle has come to rest, and the second particle has split into two equal-mass pieces that move at equal angles $\vartheta > 0$ with the horizontal direction (Figure 3b). Which of the following statements correctly describes the speeds of the two pieces?

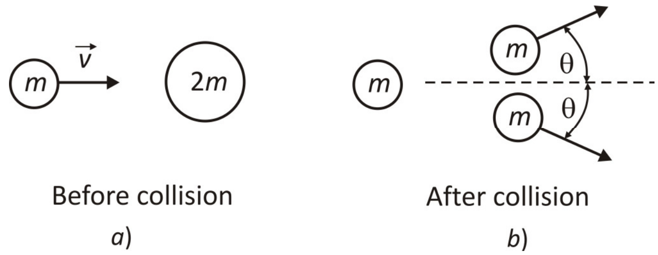

Figure 3

a) Each piece moves with speed less than *v*.
b) One of the pieces moves with speed less than *v*, the other moves with the speed greater than *v*.
c) Each piece moves with speed greater than *v*/2.
d) One of the pieces moves with speed less than *v*/2, the other moves with the speed greater than *v*/2.
e) None of the offered answers.

5. A traveler with mass m = 80 kg takes an escalator at an airport to go up one floor. The height difference between floors is h = 10 m. The escalator carries the traveler upward with vertical velocity component v_s =0,2 m/s. However, while the escalator is moving, the hurried traveler climbs the steps of the escalator at a rate of two steps in a second. The height of the one step is h_s = 0,25 m. The work done by the traveler A_t as well as the work done by the escalator A_e during the traveler's transition between two floors are (g = 10 m/s^2):

a) $A_t = 4400\,J;\quad A_e = 3600\,J$
b) $A_t = 5714.3\,J;\quad A_e = 2285.7\,J$
c) $A_t = 2556\,J;\quad A_e = 6728\,J$
d) $A_t = 4783.8\,J;\quad A_e = 3216.2\,J$
e) None of the offered answers

6. A solid cube of side $2a$ and mass M is sliding on a frictionless surface with constant speed v (Figure 4). The moment of inertia of the cube about an axis which is perpendicular to its side surface and passes through its center of mass is $I_{cm} = 2Ma^2/3$. A small obstacle is placed at the end of the table. The maximum speed v_{max} for which the cube stays on the table after it strikes the obstacle is:

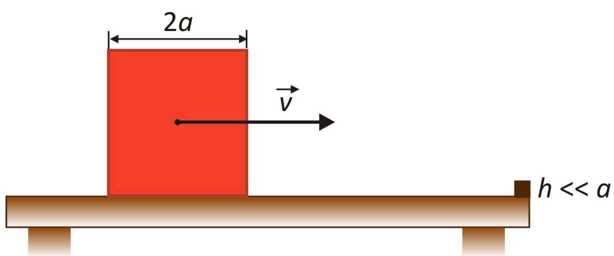

Figure 4

a) $v_{\max} = 4\sqrt{\frac{ga\left(\sqrt{2}-1\right)}{3}}$

b) $v_{\max} = \sqrt{\frac{3ga}{4}}$

c) $v_{\max} = 4\sqrt{\frac{ga\sqrt{2}}{3}}$

d) $v_{\max} = \sqrt{2ga\left(\sqrt{2}-1\right)}$

e) None of the offered answers

7. A cylinder of mass M and radius R has a radially dependent density. The cylinder starts from rest and rolls without slipping down the inclined plane of height H. At the bottom of the plane its translational speed is $v = (8gH/7)^{1/2}$. The moment of inertia of the cylinder around its axis is:

a) $I = \frac{1}{2}MR^2$
b) $I = \frac{3}{4}MR^2$
c) $I = \frac{7}{8}MR^2$
d) $I = MR^2$
e) None of the offered answers

8. Suppose that the gravitational force law between two massive objects is (Figure 5):

$$F = \gamma \frac{m_1 m_2}{r^{2+\varepsilon}}$$

where ε is a small positive number. Which of the following statements is FALSE?

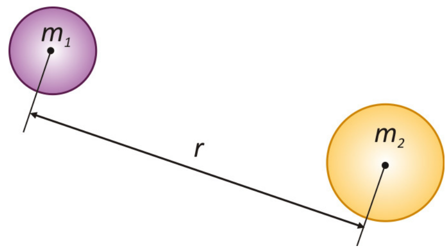

Figure 5

a) The total mechanical energy of the Sun - Earth system is conserved .
b) The angular momentum of the Earth on its orbit about the Sun is conserved.
c) The period of a planet in a circular orbit around the Sun is proportional to $r^{(3+\varepsilon)/2}$.
d) The first cosmic speed is greater than in the case of Newton’s gravitational law.
e) None of the offered answers.

9. A particle of mass *m* moves in the potential shown in Figure 6. If the particle has total energy *E* the period of its oscillations around the point $x = 0$ is:

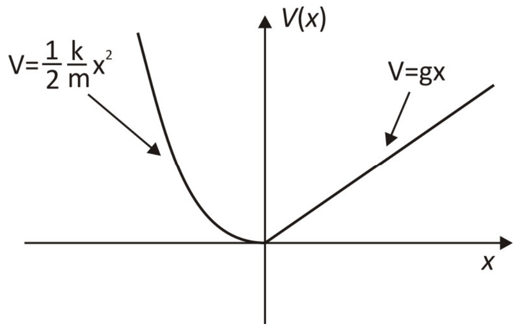

Figure 6

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

b) $T = 2\sqrt{\frac{2E}{mg^2}}$

c) $T = \pi\sqrt{\frac{m}{k}} + \sqrt{\frac{2E}{mg^2}}$

d) $T = \pi\sqrt{\frac{m}{2k}} + 2\sqrt{\frac{E}{mg^2}}$

e) None of the offered answers

10. A string with linear mass density of μ = 0,002 kg/m is passed over a light pulley and tightened by the weight of mass m (Figure 7). The other end of the string is connected to a vibrator of constant frequency f. The length of the string between the vibrator and the pulley is L = 2 m. When the mass of the weight is either m = 16 kg or m = 25 kg standing waves on the string are observed. However, no standing waves are observed with any mass between these values. What is the frequency of the vibrator f and what is the largest mass m_{max} for which standing waves on the string could be observed?

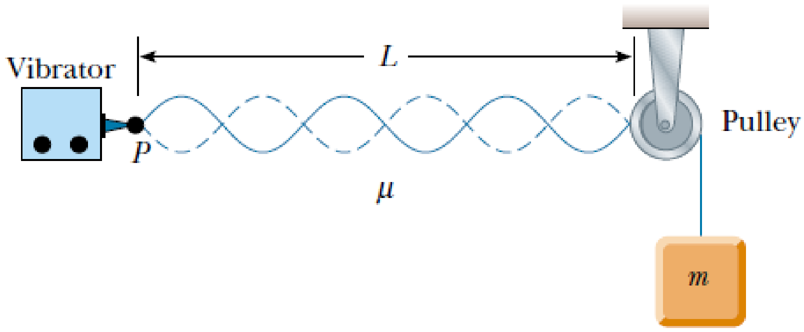

Figure 7

a) $f = 159.1\,Hz;\ m_{\max} = 81\,kg$
b) $f = 318.2\,Hz;\ m_{\max} = 81\,kg$
c) $f = 392.85\,Hz;\ m_{\max} = 49.4\,kg$
d) $f = 785.7\,Hz;\ m_{\max} = 197.5\,kg$
e) None of the offered answers

11. A glass container of mass m_p = 1 kg containing m_u =2 kg of oil whose density is ρ_u = 916 kg/m^3 rests on a beam scale (Figure 8). A block of iron of mass m_g = 2 kg and density ρ_g =7860 kg/m^3 is suspended from a spring scale and completely submerged in the oil. The equilibrium readings of the beam scale Q and spring scale F are:

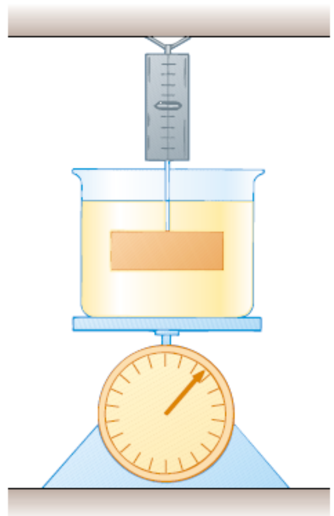

Figure 8

a) $Q = 29.43\,N;\ F = 17.33\,N$ b) $Q = 29.43\,N;\ F = 19.62\,N$ c) $Q = 31.69\,N;\ F = 19.62\,N$
d) $Q = 31.69\,N;\ F = 17.33\,N$ e) None of the offered answers

12. An incompressible, nonviscous fluid initially rests in the vertical portion of the L-shaped pipe (Figure 9a). The height of the fluid column above the valve is h = 2 m. When the valve is opened, the fluid flows to the horizontal section of the pipe. The speed of the fluid v when all of it is in the horizontal section of the pipe is (Figure 9b):

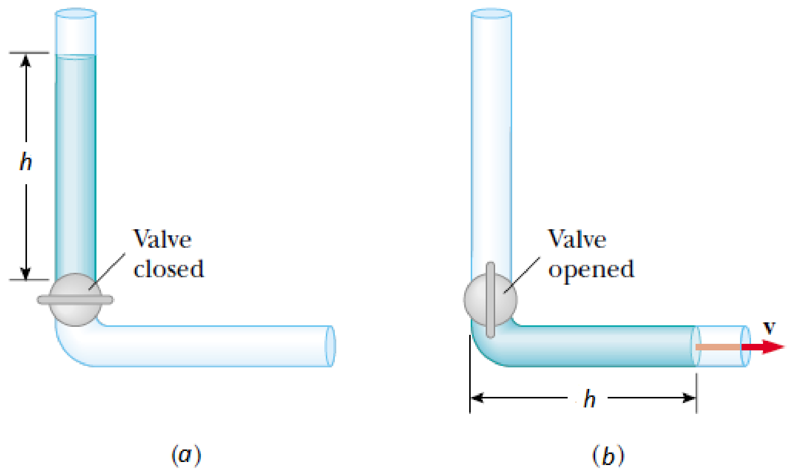

Figure 9

a) $v = 0.44\,m/s$

b) $v = 4.43\,m/s$

c) $v = 6.26\,m/s$

d) $v = 3.13\,m/s$

e) None of the offered answers

13. An ideal monatomic gas is heated slowly so that it goes from the state p_1, V_1 to the state $p_2 = 3p_1$, $V_2 = 3V_1$ in such a way that $pV^{-1} = const$. What is the molar specific heat C of this process and how much work A_{12} is done during the transition from state 1 to state 2?

a) $C = \frac{3}{2}R;\quad A_{12} = 2p_1V_1$

b) $C = \frac{5}{2}R;\quad A_{12} = 8p_1V_1$

c) $C = \frac{1}{2}R;\quad A_{12} = 4p_1V_1$

d) $C = 2R;\quad A_{12} = 4p_1V_1$

e) None of the offered answers

14. An experimenter needs to heat a small sample to the temperature of 900 K. However, the only available oven has a maximum temperature of 600 K. Can the experimenter heat the sample to 900 K by using a large lens to concentrate the radiation from the oven onto the sample as shown in Figure 10?

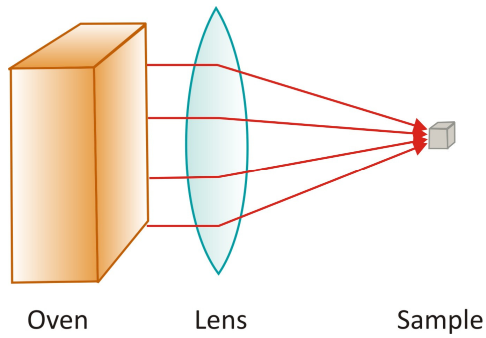

Figure 10

a) No, because it is not in accordance with the energy conservation law.
b) Yes, if the sample is placed at the focal point of the lens.
c) Yes, if the area of the front of the oven is at least 3/2 times greater than the area of the front of the sample.
d) No, because it is not in accordance with the second law of thermodynamics.
e) None of the offered answers.

15. A heat pump should heat the room to the temperature of t_p = 27°C by extracting the heat from outdoor environment whose temperature is t_s =7°C. The smallest amount of work A_{min} that should be supplied in order to deliver the heat of Q = 15000 J to the room is approximately:

a) $A_{\min} = 500\,J$ b) $A_{\min} = 1000\,J$ c) $A_{\min} = 1100\,J$

d) $A_{\min} = 2200\,J$ e) None of the offered answers

16. A light source is placed *p* = 30 cm away from a converging thin lens of focal length *f* =20 cm. What is the change *Δl in* image distance when the transparent flat block of thickness *d* =15 cm and index of refraction *n* = 1.57 is placed between the light source and the lens? Assume that the image is formed by paraxial rays.

a) $\Delta l = 102\,cm$ b) $\Delta l = 235.86\,cm$ c) $\Delta l = 47.83\,cm$
d) $\Delta l = 0\,cm$ e) None of the offered answers

17. Light of wavelength λ = 590 nm is incident on a thin film with an index of refraction n =1.38 at an angle α = 30° relative to the normal. The film is surrounded by the air ($n_{vz} \approx 1$). The minimum film thickness d_{min} for which the maximum intensity of the reflected light is obtained is:

a) $d_{\min} = 114.68\,nm$ b) $d_{\min} = 158.6\,nm$ c) $d_{\min} = 147.5\,nm$
d) $d_{\min} = 106.88\,nm$ e) None of the offered answers

18. Two identical microwave sources of frequency f = 15 GHz are separated laterally by l =20 cm (Figure 11). The microwaves emerging from sources arrive at an obstacle with a single slit of with a = 6 cm. A Fraunhofer diffraction pattern is formed on a distant screen. When the distance L is increased principal maximums from different sources get closer to each other. When the principal maximum of one image falls on the first minimum of the other image, the images are said to be just resolved. With further increase of distance L diffraction patterns from different sources are overlapped. What is the maximum distance L_{max} for which the diffraction images of two sources can be distinguished?

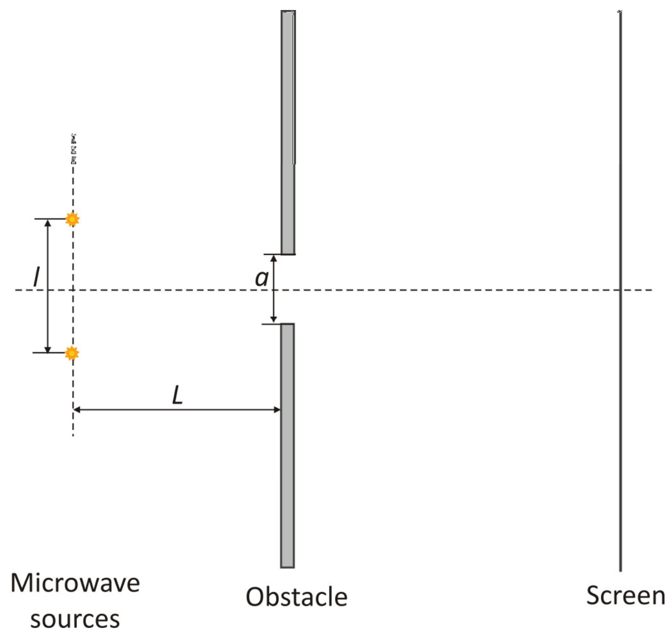

Figure 11

a) $L_{\max} = 60\,cm$ b) $L_{\max} = 113.14\,cm$ c) $L_{\max} = 120\,cm$

d) $L_{\max} = 56.57\,cm$ e) None of the offered answers

19. A small tungsten ball of radius r = 1 cm is placed in vacuum. The ball is exposed to ultraviolet radiation of wavelength λ =200 nm. The tungsten work function is A = 4.5 eV. What is the charge of the ball q when the steady state is reached ($\varepsilon_0 = 8.85 \cdot 10^{-12}$ Fm^{-1}, $e = 1.6 \cdot 10^{-19}$ C, $h = 6.62 \cdot 10^{-34}$ Js)?

a) $q = 19\, nC$
b) $q = 0.19\, nC$
c) $q = 0\, C$
d) $q = 0.38\, nC$
e) None of the offered answers

20. In order to investigate the β decay of ${}^{23}_{12}Mg$, at initial moment t = 0, the Miller Geiger counter has been turned on. During the time period τ_1 = 2 s the number of registered β - particles is n_1. During the following time period $\tau_2 = 3\tau_1$ the number of registered β - particles is 2.26 times greater. The ${}^{23}_{12}Mg$ decay constant λ is:

a) $\lambda = 0.28\, s^{-1}$

b) $\lambda = 0.56\, s^{-1}$

c) $\lambda = 0.1\, s^{-1}$

d) $\lambda = 0.34\, s^{-1}$

e) None of the offered answers