Technical University of Denmark

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Written examination, Thursday, August 22, 2019

Course name Physics 1

Course No. 10018

Duration: 4 hours

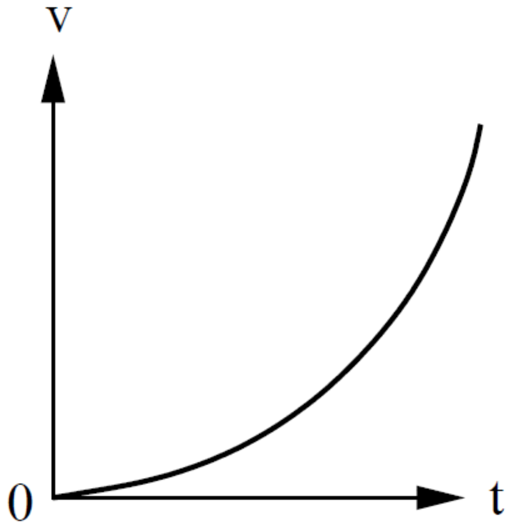
Permitted aids: All aids allowed

"Weighting": The test is judged as a whole.

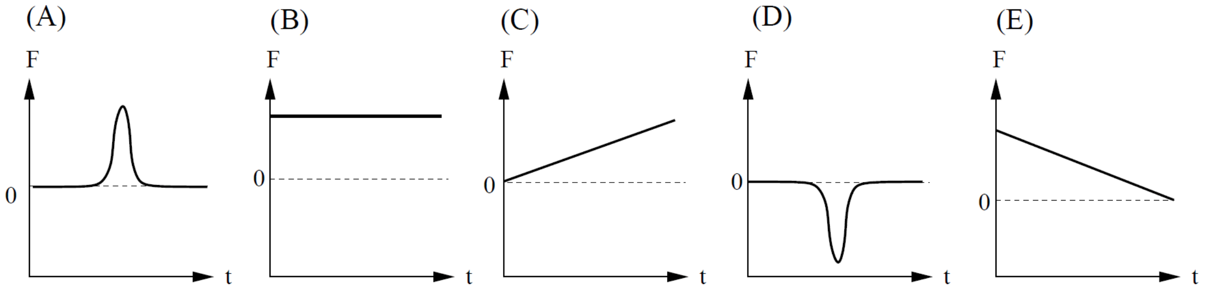
The set consists of 18 multiple choice questions that are answered in the task module at DTU Inside. All questions must be answered (if a question by mistake is not answered, it is assumed that the chosen answer is "Do not know"). Wrong answers will have a negative impact in the assessment. In some questions, only one of the options is the right answer, in other questions the right answer is given by a combination of several answers.

Question 1.

A particle starts from rest and is then subjected to a single force, $F(t)$. The figure shows the velocity of the particle as a function of time.



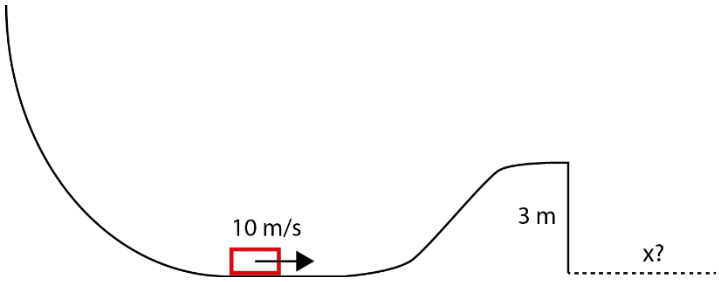
Below are shown five different examples of forces, $F(t)$. It is the same time interval in all graphs in the question.



Which of the above forces, $F(t)$, can give rise to the velocity profile shown above?

A) (A)
B) (B)
C) (C)
D) (D)
E) (E)
F) Don't know

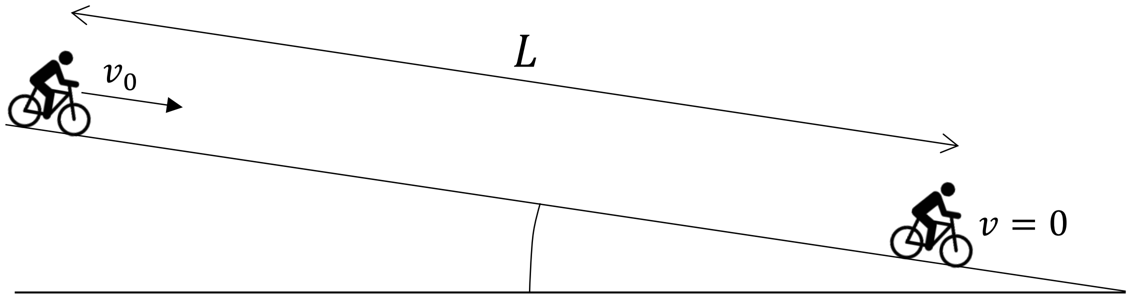
Question 2.
You are riding a sled down a hill with ice on the surface. At the bottom of the hill, you have reached a speed of 10 m/s. Your friends have built a 3 m tall ramp, which you go over. Right before the edge of the jump the surface is horizontal.



What horizontal distance do you fly? This distance starts at the edge of the jump (x on the sketch)?

A) 5.0 m
B) 7.8 m
C) 3.5 m
D) 4.2 m
E) Don’t know

Question 3.



You are riding a bike downhill. Your starting speed is v_0. You are braking so your bike is moving downhill with a constant acceleration. After a distance L, your bike comes to rest.

How long time does the braking of the bike take?

A) $t = \frac{L}{v_0}$
B) $t = \frac{2L}{v_0}$
C) $t = \frac{L}{2v_0}$
D) $t = \frac{L\cos\theta}{v_0}$
E) $t = \frac{L}{v_0\cos\theta}$
F) Don't know

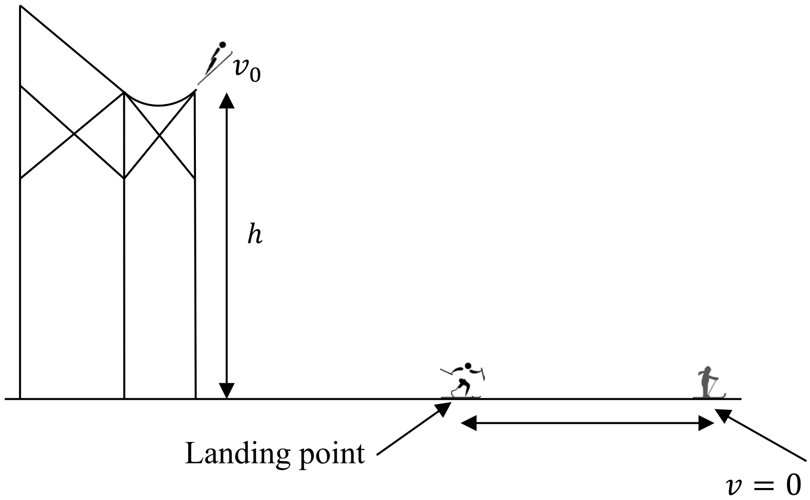
Question 4. [Continuation of previous question]

The magnitude of your constant acceleration during the braking is $a = 1.00$ m/s^2. The total mass of the bike and you is $m = 80.0$ kg. The slope of the hill relative to the horizontal is $\theta = 0.10$ rad, the starting speed is $v_0 = 10.0$ m/s, and the gravitational acceleration is $g = 9.8$ m/s^2. Drag and rolling friction during the braking can be neglected.

What is the maximum heat power $P_{\max}$ that is generated in the brake during the braking process?

A) $P_{\max} = 17$ W
B) $P_{\max} = 8.0 \cdot 10^2$ W
C) $P_{\max} = 1.6 \cdot 10^3$ W
D) $P_{\max} = 8.6 \cdot 10^3$ W
E) Don't know

Question 5.



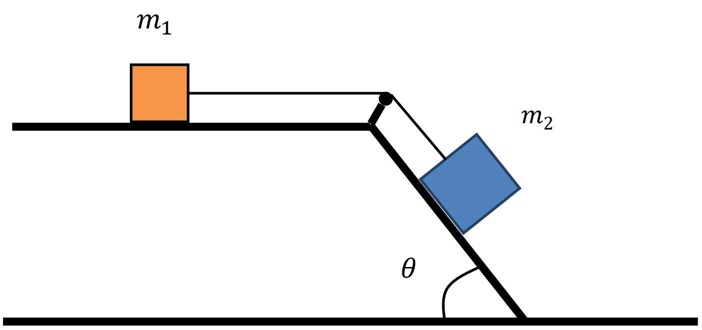
A ski jumper with mass m jumps from a ramp with speed v_0 and lands on a horizontal surface with kinetic friction coefficient, μ. While the ski jumper is in the air, the person is only subject to the gravitational force and drag. When landing, which is an ineleastic collision, the velocity of the ski jumper has the angle θ relative to horizontal. The x-component of the velocity is not changed during the landing, while the y-component remains zero. After landing the ski jumper slides a distance L before coming to a stop. During this part we assume the drag to be negligible compared to the kinetic friction. The vertical distance between starting the jump and landing, h, is shown on the figure.

Calculate the work, W that the air drag does on the ski jumper while the person is in the air

A) $W = mg(\mu L\cos^2\theta + h) - \frac{1}{2}mv_0^2$
B) $W = mg\left(\frac{\mu L}{\cos^2\theta} + h\right) - \frac{1}{2}mv_0^2$
C) $W = -mg\left(\frac{\mu L}{\cos^2\theta} + h\right) - \frac{1}{2}mv_0^2$
D) $W = -mg(\mu L\cos^2\theta + h) - \frac{1}{2}mv_0^2$
E) $W = mg(h - \mu L\cos^2\theta) + \frac{1}{2}mv_0^2$
F) $W = mg\left(h - \frac{\mu L}{\cos^2\theta}\right) + \frac{1}{2}mv_0^2$
G) $W = mg\left(\frac{\mu L}{\cos^2\theta} - h\right) - \frac{1}{2}mv_0^2$
H) $W = mg(\mu L\cos^2\theta - h) - \frac{1}{2}mv_0^2$
I) Don't know

Question 6.

Two boxes, one with mass m_1 and the other with mass m_2, are connected via a string. The box with mass m_1, is placed on a horizontal table while the other box is on an incline, having the angle θ with horizontal (see illustration). The string connecting the two boxes passes over a small massless pulley.



We assume that there is no friction between the boxes and the surfaces. The system is released. What is the magnitude of the acceleration, a, and the tension in the string, S, of the box on the incline?

A) $a = \frac{m_1 g \sin\theta}{m_1+m_2}, S = m_1 g \sin\theta$
B) $a = \frac{m_2 g \sin\theta}{m_1+m_2}, S = \frac{m_1 m_2 g \sin\theta}{m_1+m_2}$
C) $a = g\sin\theta, S = (m_1+m_2) g \sin\theta$
D) $a = g\cos\theta, S = (m_1+m_2) g \cos\theta$
E) Don't know

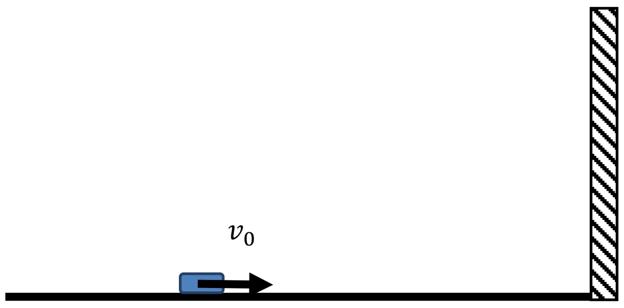
Question 7. [Continuation of previous question]

We now assume that there is dynamic friction between the boxes and the surfaces, with the coefficient of friction μ_k.

What is the magnitude of the tension in the string, S, and the acceleration, a, of the box on the incline?

A) $S = \frac{m_1}{\left(1+\frac{m_1}{m_2}\right)} g\mu_k(1-\cos\theta), a = \frac{1}{1+\frac{m_1}{m_2}} g\mu_k(1-\cos\theta)$
B) $S = \frac{m_1}{\left(1+\frac{m_1}{m_2}\right)} g(\sin\theta - \mu_k\cos\theta), a = \frac{1}{1+\frac{m_1}{m_2}} g(\sin\theta - \mu_k\cos\theta)$
C) $S = m_1 g(\sin\theta + \mu_k(1-\cos\theta)), a = g(\sin\theta + \mu_k(1-\cos\theta)) - g\mu_k$
D) $S = \frac{m_1}{\left(1+\frac{m_1}{m_2}\right)} g(\sin\theta + \mu_k(1-\cos\theta)), a = \frac{1}{1+\frac{m_1}{m_2}} g(\sin\theta + \mu_k(1-\cos\theta)) - g\mu_k$
E) Don't know

Question 8.
A hockey puck with a mass m slides without rotating on a table with a constant coefficient of friction (see drawing). At a distance D from the vertical wall the horizontal velocity of the hockey puck is positive and v_0. Right before the hockey puck hits the wall, it has the velocity v_1, and right after the collision it has the velocity v_2. After the collision, the hockey puck has the velocity $v_3 = 0\ \mathrm{m/s}$ at some distance P from the wall. Note that P is not marked on the drawing because it is not given where it is relative to D.



Assuming that D, P, v_0, v_1 are known, what is then v_2?

A) $v_2 = -\sqrt{\frac{P}{D}(v_0^2 - v_1^2)}$
B) $v_2 = -\sqrt{\frac{P}{D}(v_1^2 - v_0^2)}$
C) $v_2 = \sqrt{\frac{P}{D}(v_1^2 - v_0^2)}$
D) $v_2 = \sqrt{\frac{P}{D}(v_0^2 - v_1^2)}$
E) $v_2 = -v_1$
F) Don't know

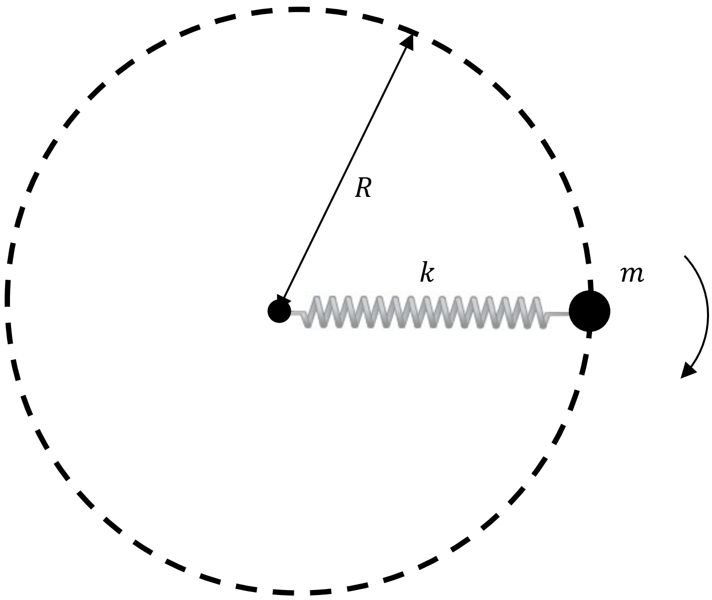
Question 9. [Continuation of previous question]

Which of the following statement(s) is(are) true?

A) If the collision is fully elastic, then $P > D$
B) If the collision is fully elastic and $2v_1^2 > v_0^2$, then $P > D$
C) If the collision is not fully elastic and $P = D$, then the energy loss is $\Delta K_{\text{collision}} = \frac{1}{2}m(v_0^2 - 2v_1^2)$ during the collision.
D) If the collision is not fully elastic and $P = D$, then the energy loss is $\Delta K_{\text{collision}} = \frac{1}{2}m(v_1^2 - 2v_0^2)$ during the collision.
E) If the collision is fully inelastic then $P = D$.
F) None of the above statements is true.
G) Don't know

Question 10.

A particle with the mass $m = 200$ g, is placed at the end of a massless spring. The other end of the spring can rotate freely around an axis. Gravitation and friction can be neglected. The particle performs circular motion with an angular speed of $\omega = 2.0\ \mathrm{s}^{-1}$. The radius of the circular motion is $R = 1.0$ m. The spring constant is $k = 5.0\ \mathrm{N/m}$. Seen from above the situation looks like this

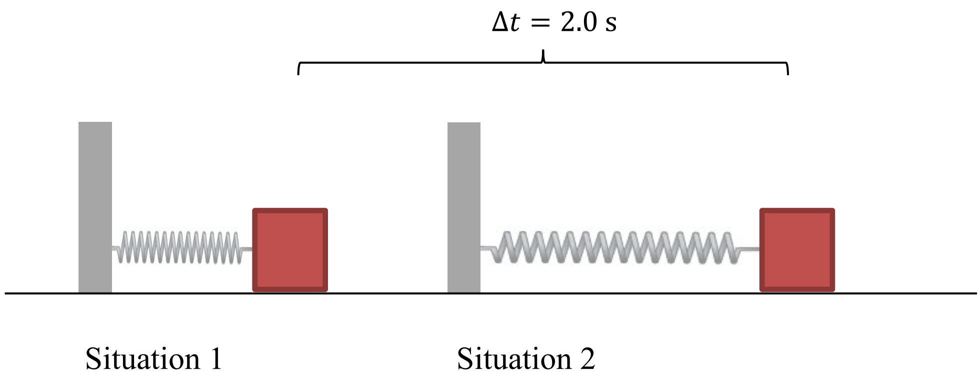


Which of the following lengths is closest to the equilibrium length of the spring?

A) 0.16 m
B) 0.20 m
C) 0.84 m
D) 0.92 m
E) 1.16 m
F) Don't know

Question 11.

A 2.0 kg block is attached to a compressed spring (horizontally on a frictionless plane), with an unknown spring constant. Once you release the spring (Situation 1), it takes 2.0 seconds for the block to reach its furthest point (Situation 2), before it starts to come back.



What is the spring constant?

A) 1.6 kg/s^2
B) 3.1 kg/s^2
C) 4.9 kg/s^2
D) 20 kg/s^2
E) Don't know

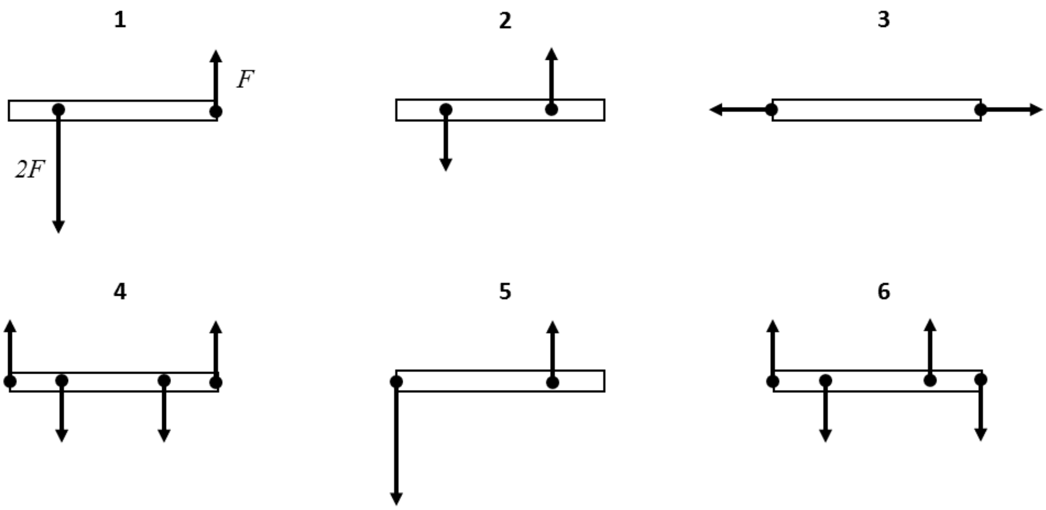
Question 12.

You have a stationary mass attached to a compressed spring that is facing horizontal (on a frictionless plane). You give the mass a quick whack with a hammer, such that the mass has an initial velocity of 6.0 m/s. The amplitude of the oscillation of the mass is 4.0 m.

How far is the mass from its starting position after 2.0 s?

A) 0.50 m
B) 0.56 m
C) 0.78 m
D) 1.0 m
E) 1.1 m
F) 2.0 m
G) 2.3 m
H) 4.0 m
I) Don't know

Question 13.



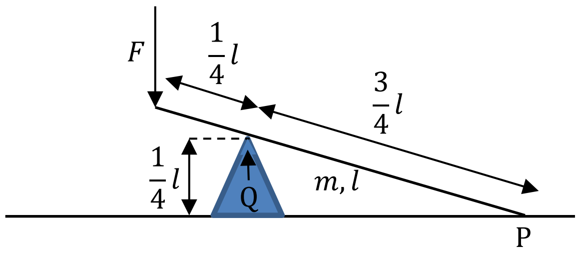
A rod of length L lies on a smooth horizontal surface. The rod is subject to a number of forces of magnitude F or $2F$ in 6 different situations. In the figure, the rod is viewed from above and all forces are parallel with the surface.

In which of the situations 1-6 is the rod in static equilibrium?

A) Situation 1
B) Situation 2
C) Situation 3
D) Situation 4
E) Situation 5
F) Situation 6
G) None of them
H) Don't know

Question 14.

A thin, homogeneous rod has the mass m and length l. The rod is in contact with the surface at a point, P, and with a blue triangle in a point Q. The distance from the point P to the point Q along the rod is $\frac{3}{4}l$. In the opposite end a vertical force, F, is applied. The triangle has the height $\frac{1}{4}l$. If the force, F, is sufficiently large, the rod will begin to rotate around the contact point Q.



What can be said about the minimum value of F required to make the normal force on the rod in P vanish?

A) $F > mg$
B) $F = mg$
C) $F < mg$
D) Don't know

Question 15. [Continuation of previous question]

We now apply the force, $F = 100$ N. The other parameters are $m = 8.0$ kg and $l = 2.0$ m.

What is the size of the angular acceleration of the rod, α, immediately after the force is applied?

A) $\alpha = 0\ \mathrm{s}^{-2}$ (the force in not sufficiently large to make the rod rotate)
B) $\alpha = 0.34\ \mathrm{s}^{-2}$
C) $\alpha = 0.95\ \mathrm{s}^{-2}$
D) $\alpha = 2.2\ \mathrm{s}^{-2}$
E) $\alpha = 2.3\ \mathrm{s}^{-2}$
F) $\alpha = 3.8\ \mathrm{s}^{-2}$
G) Don't know

Question 16.
A healthy person with a body temperature of 37.0 °C eats 0.500 kg of ice with temperature -18.0 °C.

How much energy must the body consume to raise the eaten water ice to the body temperature?

A) 96 kJ
B) 167 kJ
C) 526 kJ
D) 430 kJ
E) 263 kJ
F) Don't know

Question 17.
You are driving a car from southern Spain, where the outside temperature is 40 °C, to northern Sweden where the temperature is 0.0 °C. All the tires in your car start with an air pressure of 2.2 bar and each tire contains 1.2 mol.

If you assume that the air inside the tires goes through an isochoric process, what is then the pressure inside the tires when you reach northern Sweden?

A) 1.9 bar
B) 15.0 bar
C) 0 bar
D) 3.7 bar
E) Don’t know

Question 18. [Continuation of previous question]
You are now changing to winter tires, which need to be pumped up. If you pressurize the air inside the pump adiabatically, how much is the temperature of the air then rising if you start from atmospheric pressure and go to 2.2 bar?

A) 0 °C
B) 69 °C
C) 342 °C
D) 50 °C
E) Don’t know