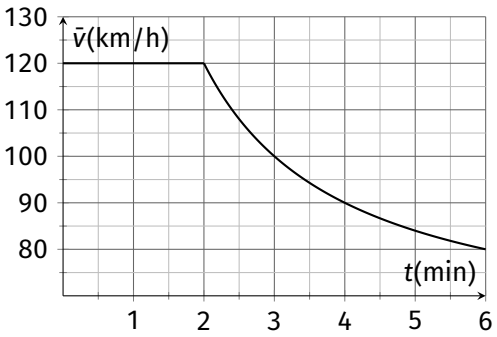
LATVIJAS 50. ATKLĀTĀ FIZIKAS OLIMPIĀDE

Year 9

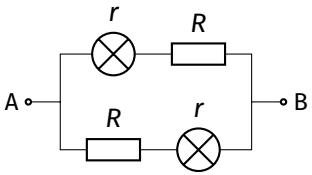
9-1° *Visible and invisible* (3 p) Three pairs of pictures of a hot coffee mug in different setups are shown on the screen. In each pair, the first picture is taken with a thermographic camera, the second one with a regular camera. The first pair of pictures is taken without any filter; in the second pair, black PET film is placed in front of the mug; in the third pair – a glass plate. Give a detailed physical interpretation of the differences between the pictures. Print-outs of the pictures are available upon request at the front desk.

9-2° *Highway and city* (2 p) A car moving on a highway with constant speed v_1, enters a city and continues with constant speed v_2. The graph shows how the average speed $\bar{v}$ of the car changes in time t. What is the speed of the car in the city?



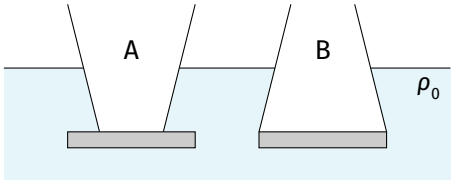
9-3° *Melting and heating* (2 p) A calorimeter is filled with a mixture of water and ice at thermal equilibrium. After heating the mixture up with an immersion heater for time t_1, the ice melted entirely and after another time interval t_2 the water warmed up by ΔT. Neglecting the heat capacity of the calorimeter, determine the ratio of the initial mass of water M to the initial mass of ice m. Specific heat capacity of water is c, its latent heat of fusion is λ.

9-4° *Two lamps* (2 p) The figure shows a circuit of a combination of two identical lamps and two resistors. Potential difference between points A and B is kept constant. The resistance of each resistor is $R = 3\,\Omega$. If one of the lamps is substituted by a resistor of resistance R, the power dissipated in the circuit will increase by a factor of $k = 2$. Determine the resistance r of the lamp.



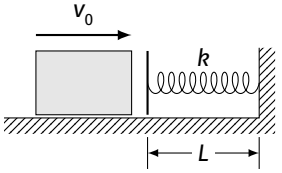
9-5° *Composite plate* (2 p) A stack of $N_0 = 50$ thin glass plates is placed in oil. Refractive index of the kth plate is $n_k = n_{k-1} - \Delta n$ where $\Delta n = 0{,}01$. Refractive index of oil $n_0 = 1{,}60$. Each plate is $d = 1$ mm thick. A laser beam is incident on the first plate at angle $\theta = 60°$. Determine the maximum distance the beam has travelled along the x axis in the stack.

9-6° *Attached bottom* (3 p) The bottom of a truncated conical container is covered with a light disc while the top is open. The container is partially submerged in water (Fig. A). If the container is filled with at least 1 kg of water of density ρ_0, the disc falls off. Suppose now that instead of water, the container is filled with 1 kg of other liquid of density ρ. Will the disc fall off now? Would your answer change if the container were turned upside down as in Fig. B?



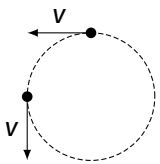
9-7° *Ice jam* (2 p) Small ice floes covering $\eta = 20\,\%$ of the surface of the river are drifting with the speed of $v = 4\,\frac{\text{km}}{\text{h}}$. At some point, a jam is formed where the floes cover the whole surface of water without piling up. At what speed u does the boundary of the jam extend?

9-8° *Soft recoil* (3 p) A box of mass $m = 0{,}5$ kg is sliding on a horizontal surface towards a wall. In order to soften the impact, a spring of length $L = 30$ cm and stiffness $k = 50\,\frac{\text{N}}{\text{m}}$ is fixed to the wall (see figure). The speed of the box just before it came in contact with the spring was $v_0 = 1{,}2\,\frac{\text{m}}{\text{s}}$, and its speed just after it lost contact with the spring was $v = 0{,}8\,\frac{\text{m}}{\text{s}}$. Determine (a) the friction force between the box and the surface; (b) the minimum distance between the box and the wall.



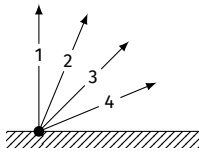
9-9° *Multiple choice questions* (3 p) For each question there is one correct answer. Justify your choice. Answers without justification will receive zero marks.

(1) Two flies are running on a circle with equal speeds v. What is the speed of one fly relative to the other?



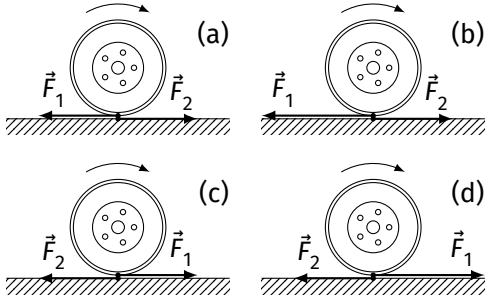
(a) 0
(b) v
(c) $v\sqrt{2}$
(d) $2v$

(2) Four objects are launched simultaneously with equal speeds (see fig.). Which of the objects (i) will be the last one to hit the ground; (ii) will hit the ground furthest from the launching point?

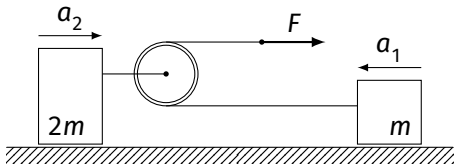


(a) (i) 1 (ii) 4
(b) (i) 4 (ii) 2
(c) (i) 1 (ii) 3
(d) (i) all at the same time (ii) 4

(3) Which of the figures correctly represents the friction forces acting on a car's drive wheel ($\vec{F}_1$) and on the surface of the road ($\vec{F}_2$)? The car accelerates and moves to the right as shown in the figures.

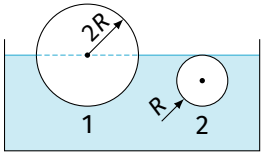


(4) Two blocks of masses m and $2m$ are placed on a smooth horizontal surface and connected with a light unstretchable string. The string goes over a pulley, and the force F is applied to its free end. Compare the accelerations of the blocks.



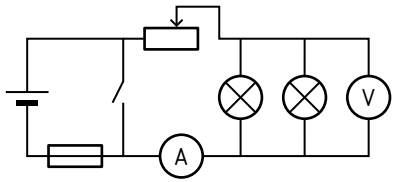
(a) $a_1 = 4a_2$
(b) $a_1 = 2a_2$
(c) $a_1 = a_2$
(d) $a_1 = 0{,}5a_2$

(5) Two balls of radii $R_1 = 2R$ and $R_2 = R$ are floating in water. Compare the densities of the balls.



(a) $\rho_1 = 0{,}25\rho_2$
(b) $\rho_1 = 4\rho_2$
(c) $\rho_1 = \rho_2$
(d) $\rho_1 = 0{,}5\rho_2$

(6) The ammeter and the voltmeter used in the circuit are ideal, potential difference across the cell is constant. What might have happened in the circuit if the reading of the ammeter has decreased (but is still non-zero), but the reading of the voltmeter has increased?



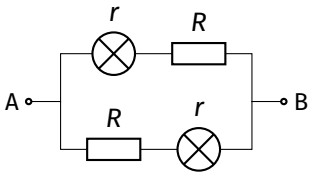
(a) One of the lamps has blown out.
(b) Both lamps have blown out.
(c) The slider of a variable resistor has been moved to the right.
(d) The switch has been closed.

LATVIJAS 50. ATKLĀTĀ FIZIKAS OLIMPIĀDE

Year 10

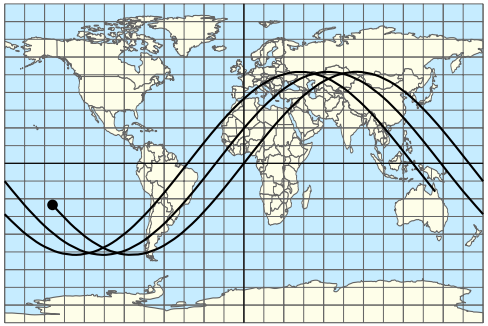
10-1° *Visible and invisible* (3 p) Three pairs of pictures of a hot coffee mug in different setups are shown on the screen. In each pair, the first picture is taken with a thermographic camera, the second one with a regular camera. The first pair of pictures is taken without any filter; in the second pair, black PET film is placed in front of the mug; in the third pair – a glass plate. Give a detailed physical interpretation of the differences between the pictures. Print-outs of the pictures are available upon request at the front desk.

10-2° *Two lamps* (2 p) The figure shows a circuit of a combination of two identical lamps and two resistors. Potential difference between points A and B is kept constant. The resistance of each resistor is $R = 3\,\Omega$. If one of the lamps is substituted by a resistor of resistance R, the power dissipated in the circuit will increase by a factor of $k = 2$. Determine the resistance r of the lamp.



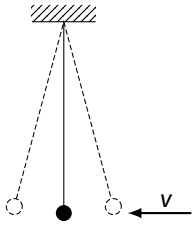
10-3° *Crazy turtles* (3 p) N turtles initially sitting in the corners of a regular N-gon simultaneously start moving at a constant speed v so that the first one is always heading towards the second, the second – towards the third and so on. Where and after how much time will they meet if the initial distance between any two neighbour turtles is L?

10-4° *ISS* (3 p) As the International Space Station (ISS) moves in space, projection of its position vector in the reference frame of the centre of Earth onto the surface of Earth traces a line shown in the figure. The radius of Earth $R = 6380$ km, free-fall acceleration on the surface of Earth $g = 9{,}8\,\frac{\mathrm{m}}{\mathrm{s}^2}$. Assuming that the ISS is on a circular orbit, estimate the height of this orbit above the surface of Earth.

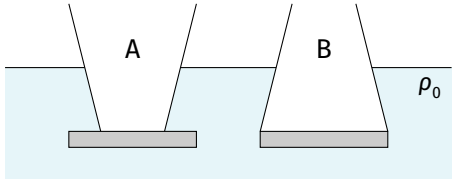


10-5° *Bouncing downhill* (3 p) An elastic ball is released from height H above a plane inclined at angle α. What is the distance between the first bouncing point and the second? Assume collisions are perfectly elastic and the free-fall acceleration is g.

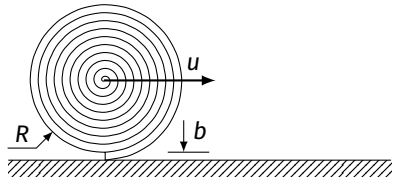
10-6° *Archery tricks* (3 p) An archer shoots at the target, which oscillates on a string of length L with angular amplitude φ_0 in the plane of the trajectory of the arrow. Right before the arrow got stuck in the target, it was flying horizontally with velocity v, and the target was at the lowest point of its trajectory. After the impact, the target reaches the maximum angle φ_1. Determine the ratio $\frac{m}{M}$ of arrow and target masses. Assume that the arrow and the target are point particles and ignore air resistance. Free-fall acceleration is g.



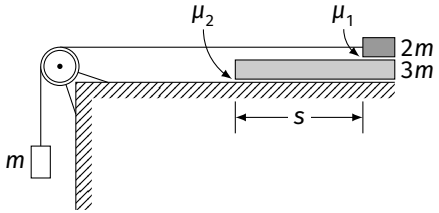
10-7° *Attached bottom* (3 p) The bottom of a truncated conical container is covered with a light disc while the top is open. The container is partially submerged in water (Fig. A). If the container is filled with at least 1 kg of water of density ρ_0, the disc falls off. Suppose now that instead of water, the container is filled with 1 kg of other liquid of density ρ. Will the disc fall off now? Would your answer change if the container were turned upside down as in Fig. B?



10-8° *Rolled-up mat* (4 p) A long thin rubber mat is tightly rolled up so that the radius of the roll is R. The thickness of the mat $b \ll R$, its mass per unit length is μ. Assume that the mat never slips and ignore its elastic deformations. The mat is then unrolled keeping the speed u of its axis constant. Estimate the power P needed to keep unrolling the mat as a function of its current radius r. Free-fall acceleration is g.



10-9° *A lot of friction* (4 p) A weight of mass m, a block of mass $2m$ and a plank of mass $3m$ are initially held at rest. The distance from the block to the edge of the plank is s. When the system is released, the block slides on the plank and the plank slides on the table. Dynamic friction factor between the block and the plank is μ_1, while that between the plank and the table is μ_2. Determine the time in which the block will reach the edge of the plank. Assume that the pulley and the string are massless and that in considered time, the plank will not reach the pulley.



10-10° *Multiple choice questions* (3 p) For each question there is one correct answer. Justify your choice. Answers without justification will receive zero marks.

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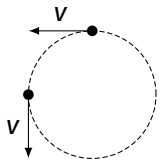

(a) 0
(b) v
(c) $v\sqrt{2}$
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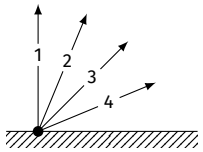
(2) Four objects are launched simultaneously with equal speeds (see fig.). Which of the objects (i) will be the last one to hit the ground; (ii) will hit the ground furthest from the launching point?



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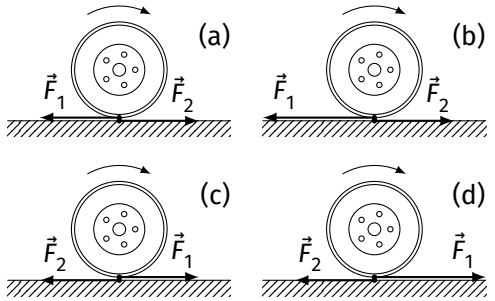
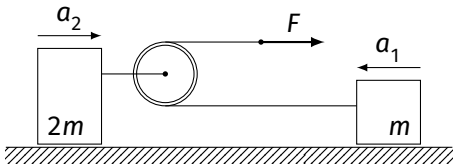
(3) Which of the figures correctly represents the friction forces acting on a car's drive wheel ($\vec{F}_1$) and on the surface of the road ($\vec{F}_2$)? The car accelerates and moves to the right as shown in the figures.



(4) Two blocks of masses m and $2m$ are placed on a smooth horizontal surface and connected with a light unstretchable string. The string goes over a pulley, and the force F is applied to its free end. Compare the accelerations of the blocks.



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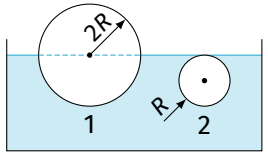
(c) $a_1 = a_2$
(d) $a_1 = 0{,}5a_2$

(5) Two balls of radii $R_1 = 2R$ and $R_2 = R$ are floating in water. Compare the densities of the balls.



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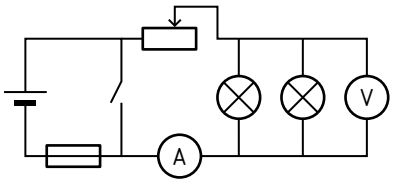
(6) The ammeter and the voltmeter used in the circuit are ideal, potential difference across the cell is constant. What might have happened in the circuit if the reading of the ammeter has decreased (but is still non-zero), but the reading of the voltmeter has increased?



(a) One of the lamps has blown out.
(b) Both lamps have blown out.
(c) The slider of a variable resistor has been moved to the right.
(d) The switch has been closed.

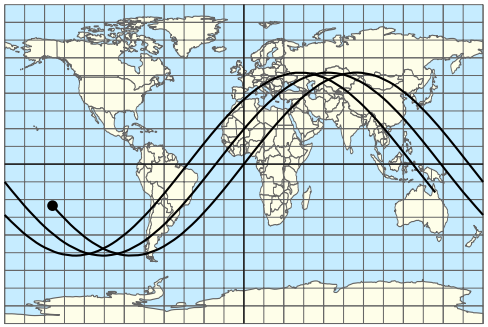
LATVIJAS 50. ATKLĀTĀ FIZIKAS OLIMPIĀDE

Year 11

11-1° *Visible and invisible* (3 p) Three pairs of pictures of a hot coffee mug in different setups are shown on the screen. In each pair, the first picture is taken with a thermographic camera, the second one with a regular camera. The first pair of pictures is taken without any filter; in the second pair, black PET film is placed in front of the mug; in the third pair – a glass plate. Give a detailed physical interpretation of the differences between the pictures. Which physical quantity, in your oppinion, might correspond to the colour in the thermograms? Give a reasoning based on the features seen in the pictures. Print-outs of the pictures are available upon request at the front desk.

11-2° *Firefly* (2 p) A point-like light source is approaching a thin converging lens and crosses its principal axis at the distance $d = 30\,\text{cm}$ from the lens. At this moment, the velocity of the source makes an angle $\alpha = 30°$ with the axis. Determine the angle β between the velocity of the image and the axis at the same moment in time. Focal length of the lens $F = 20\,\text{cm}$.

11-3° *ISS* (3 p) As the International Space Station (ISS) moves in space, projection of its position vector in the reference frame of the centre of Earth onto the surface of Earth traces a line shown in the figure. The radius of Earth $R = 6380\,\text{km}$, free-fall acceleration on the surface of Earth $g = 9{,}8\,\frac{\text{m}}{\text{s}^2}$. Assuming that the ISS is on a circular orbit, estimate the height of this orbit above the surface of Earth.



11-4° *A ball on a string* (2 p) One end of an unstretchable string is fixed, while the other one is tied to a small ball. Initially, the ball is held at rest and the string is horizontal. The ball is then released. At what point of the ball's trajectory is its acceleration horizontal?

11-5° *Walking habits* (4 p)

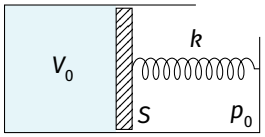
(a) Estimate the most effortless walking speed for a person if the length of his/her legs $L = 90\,\text{cm}$ and the length of each step $w = 60\,\text{cm}$. During a natural walk, the maximum angle the leg forms with a vertical is approximately the same for all people.

(b) Does the speed of a natural walk depend on the walker's leg length L? If yes, then how?

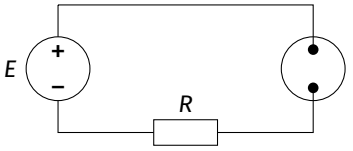
Assume that proportions of a human body are approximately the same for all people and that the maximum force produced by a muscle is proportional to its cross-section area.

(c) Does the maximum running speed depend on the walker's size? If yes, then how?

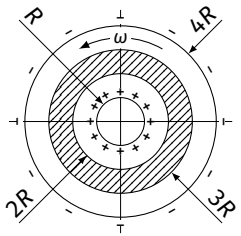
11-6° *Piston and spring* (4 p) A cylinder is split in two parts by a massless piston of area S. The left part is filled with helium, while the right part is open to the atmosphere at pressure p_0. A spring of stiffness k holds the piston in equilibrium. Initially, the spring is not deformed and the volume V_0 of the left part satisfies $p_0 S^2 = kV_0$. Ignore heat loss to the environment. Determine the molar heat capacity of helium in this system.



11-7° *Stabilisation* (4 p) The current I through an electric arc decreases with the increase of potential difference U across it so that $U = a + b/I$. A resistor is added in series with the arc to stabilise it against fluctuations of current. Determine the range of values of R for which the arc is stable and dissipates no less than half of the power drawn from the ideal source of EMF E. For numerical estimates use $a = 55\,\text{V}$, $b = 50\,\text{W}$ and $E = 100\,\text{V}$.

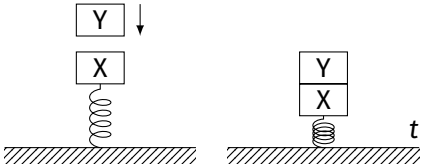


11-8° *Dielectric kebab* (5 p) A dielectric pipe of inner radius $2R$, outer radius $3R$ and relative permittivity ε is placed coaxially between two cylindrical surfaces of radii R and $4R$ carrying linear charge density λ and $-\lambda$, respectively (see fig.). The pipe is rotating around its axis with an angular speed ω. Assume that $\omega R \ll c$ and that relative permeability of the pipe $\mu = 1$. Determine how the magnitude of (a) electric and (b) magnetic field changes with the distance r from the axis. What is the direction of each of these fields?



11-9° *Multiple choice questions* (3 p) For each question there is one correct answer. Justify your choice. Answers without justification will receive zero marks.

(1) Block Y of mass m_Y is dropped onto block X, which is attached to a vertical spring, and sticks to it. At time t when the blocks momentarily come to rest, block Y exerts a force of magnitude F_Y on block X, and block X exerts a force of magnitude F_X on block Y. Which of the following correctly relates the three forces at time t?



(a) $F_X = F_Y > m_Y g$
(b) $F_Y = m_Y g > F_X$
(c) $F_X = F_Y = m_Y g$
(d) $F_Y > F_X = m_Y g$

(2) In a room where the temperature is 300 K, a football has been inflated to a gauge pressure of 89 kPa. The football is then taken to the field, where the temperature is 270 K. What will the football's gauge pressure be when its temperature becomes equal to the temperature of the air on the field? Assume the ball volume did not change and that the atmospheric pressure that day was 101 kPa.

(a) 110 kPa
(b) 89 kPa
(c) 70 kPa
(d) 40 kPa

(3) A large air balloon is filled with 125 m^3 of helium. It is moving horizontally at 4 $\frac{m}{s}$, maintaining constant altitude of 500 m above ground. Air density is 1,29 $\frac{kg}{m^3}$, helium density is 0,17 $\frac{kg}{m^3}$. Which of the energies of the balloon, kinetic or potential, is greater in the reference frame of the ground?

(a) kinetic
(b) potential
(c) both are equal
(d) depends on the temperature

(4) Two satellites are in circular orbits around Earth. The radius of Earth is R. Satellite 1 has mass m and orbital radius $2R$. Satellite 2 has mass $2m$ and orbital radius $3R$. Which of the following correctly compares the magnitude F of the force exerted by Earth on each satellite and the speed of of each satellite?

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(b) $F_1 > F_2$, $v_1 < v_2$
(c) $F_1 < F_2$, $v_1 > v_2$
(d) $F_1 < F_2$, $v_1 < v_2$

(5) If a car has a siren with a frequency of 500 Hz and drives towards a boy with a velocity of 20 $\frac{m}{s}$, what is the frequency the boy hears? The speed of sound in the air is 343 $\frac{m}{s}$.

(a) 531,0 Hz
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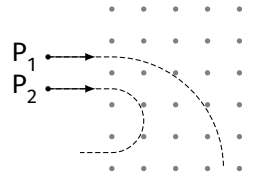
(6) Two charged particles travelling with the same velocity enter a region in which there is a uniform magnetic field directed out of the the plane of the drawing as shown. The particles follow different paths. Which of the following statements must be true?



(a) P_1 has smaller mass than P_2.
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(d) P_1 has greater mass-to-charge ratio than P_2.

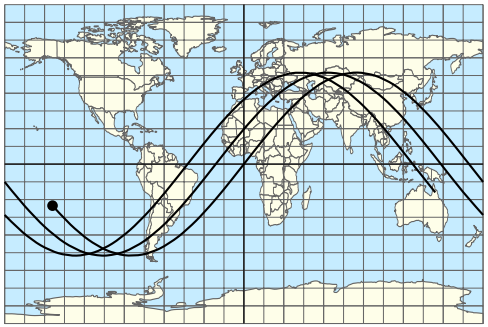
LATVIJAS 50. ATKLĀTĀ FIZIKAS OLIMPIĀDE

Year 12

12-1° *Visible and invisible* (3 p) Three pairs of pictures of a hot coffee mug in different setups are shown on the screen. In each pair, the first picture is taken with a thermographic camera, the second one with a regular camera. The first pair of pictures is taken without any filter; in the second pair, black PET film is placed in front of the mug; in the third pair – a glass plate. Give a detailed physical interpretation of the differences between the pictures. Which physical quantity, in your oppinion, might correspond to the colour in the thermograms? Give a reasoning based on the features seen in the pictures. Print-outs of the pictures are available upon request at the front desk.

12-2° *Firefly* (2 p) A point-like light source is approaching a thin converging lens and crosses its principal axis at the distance $d = 30\,\text{cm}$ from the lens. At this moment, the velocity of the source makes an angle $\alpha = 30°$ with the axis. Determine the angle β between the velocity of the image and the axis at the same moment in time. Focal length of the lens $F = 20\,\text{cm}$.

12-3° *ISS* (3 p) As the International Space Station (ISS) moves in space, projection of its position vector in the reference frame of the centre of Earth onto the surface of Earth traces a line shown in the figure. The radius of Earth $R = 6380\,\text{km}$, free-fall acceleration on the surface of Earth $g = 9{,}8\,\frac{\text{m}}{\text{s}^2}$. Assuming that the ISS is on a circular orbit, estimate the height of this orbit above the surface of Earth.



12-4° *A ball on a string* (2 p) One end of an unstretchable string is fixed, while the other one is tied to a small ball. Initially, the ball is held at rest and the string is horizontal. The ball is then released. At what point of the ball's trajectory is its acceleration horizontal?

12-5° *Walking habits* (4 p)

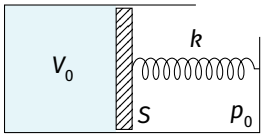
(a) Estimate the most effortless walking speed for a person if the length of his/her legs $L = 90\,\text{cm}$ and the length of each step $w = 60\,\text{cm}$. During a natural walk, the maximum angle the leg forms with a vertical is approximately the same for all people.

(b) Does the speed of a natural walk depend on the walker's leg length L? If yes, then how?

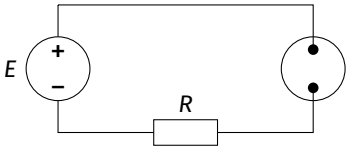
Assume that proportions of a human body are approximately the same for all people and that the maximum force produced by a muscle is proportional to its cross-section area.

(c) Does the maximum running speed depend on the walker's size? If yes, then how?

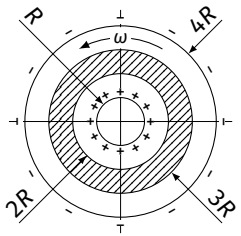
12-6° *Piston and spring* (4 p) A cylinder is split in two parts by a massless piston of area S. The left part is filled with helium, while the right part is open to the atmosphere at pressure p_0. A spring of stiffness k holds the piston in equilibrium. Initially, the spring is not deformed and the volume V_0 of the left part satisfies $p_0 S^2 = kV_0$. Ignore heat loss to the environment. Determine the molar heat capacity of helium in this system.



12-7° *Stabilisation* (4 p) The current I through an electric arc decreases with the increase of potential difference U across it so that $U = a + b/I$. A resistor is added in series with the arc to stabilise it against fluctuations of current. Determine the range of values of R for which the arc is stable and dissipates no less than half of the power drawn from the ideal source of EMF E. For numerical estimates use $a = 55\,\text{V}$, $b = 50\,\text{W}$ and $E = 100\,\text{V}$.

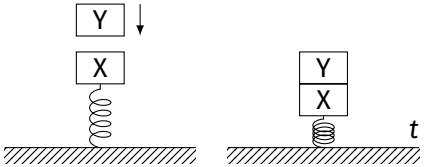


12-8° *Dielectric kebab* (5 p) A dielectric pipe of inner radius $2R$, outer radius $3R$ and relative permittivity ε is placed coaxially between two cylindrical surfaces of radii R and $4R$ carrying linear charge density λ and $-\lambda$, respectively (see fig.). The pipe is rotating around its axis with an angular speed ω. Assume that $\omega R \ll c$ and that relative permeability of the pipe $\mu = 1$. Determine how the magnitude of (a) electric and (b) magnetic field changes with the distance r from the axis. What is the direction of each of these fields?



12-9° *Multiple choice questions* (3 p) For each question there is one correct answer. Justify your choice. Answers without justification will receive zero marks.

(1) Block Y of mass m_Y is dropped onto block X, which is attached to a vertical spring, and sticks to it. At time t when the blocks momentarily come to rest, block Y exerts a force of magnitude F_Y on block X, and block X exerts a force of magnitude F_X on block Y. Which of the following correctly relates the three forces at time t?



(a) $F_X = F_Y > m_Y g$
(b) $F_Y = m_Y g > F_X$
(c) $F_X = F_Y = m_Y g$
(d) $F_Y > F_X = m_Y g$

(2) In a room where the temperature is 300 K, a football has been inflated to a gauge pressure of 89 kPa. The football is then taken to the field, where the temperature is 270 K. What will the football's gauge pressure be when its temperature becomes equal to the temperature of the air on the field? Assume the ball volume did not change and that the atmospheric pressure that day was 101 kPa.

(a) 110 kPa
(b) 89 kPa
(c) 70 kPa
(d) 40 kPa

(3) A large air balloon is filled with 125 m^3 of helium. It is moving horizontally at 4 $\frac{m}{s}$, maintaining constant altitude of 500 m above ground. Air density is 1,29 $\frac{kg}{m^3}$, helium density is 0,17 $\frac{kg}{m^3}$. Which of the energies of the balloon, kinetic or potential, is greater in the reference frame of the ground?

(a) kinetic
(b) potential
(c) both are equal
(d) depends on the temperature

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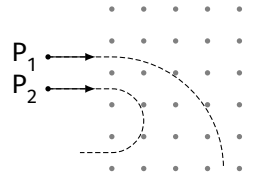

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