Technical University of Denmark

Written training exam, Physics (PG) December 2024

Permitted aids: All aids allowed, but no internet access.

“Weighting”: The response will be evaluated as a whole.

The set consists of 20 multiple-choice questions. Some questions have one correct answer, while in others, the correct answer is a combination of multiple options.

Question 1.

Independent observations of a new electric car have found that it weighs $m = (1.7 \pm 0.1) \cdot 10^3$ kg and that its maximum acceleration is $a = 12 \pm 1$ m/s^2.

What is the maximum force the engine can deliver?

A) 141 ± 1 N
B) 20 ± 2 N
C) 20.4 ± 0.2 kN
D) 20 ± 2 kN
E) 20400.00 ± 0.08 N
F) 40 ± 2 kN
G) 140 ± 30 kN
H) 20.4 ± 2.1 kN
I) $20. \pm 2.1$ kN
J) Don't know

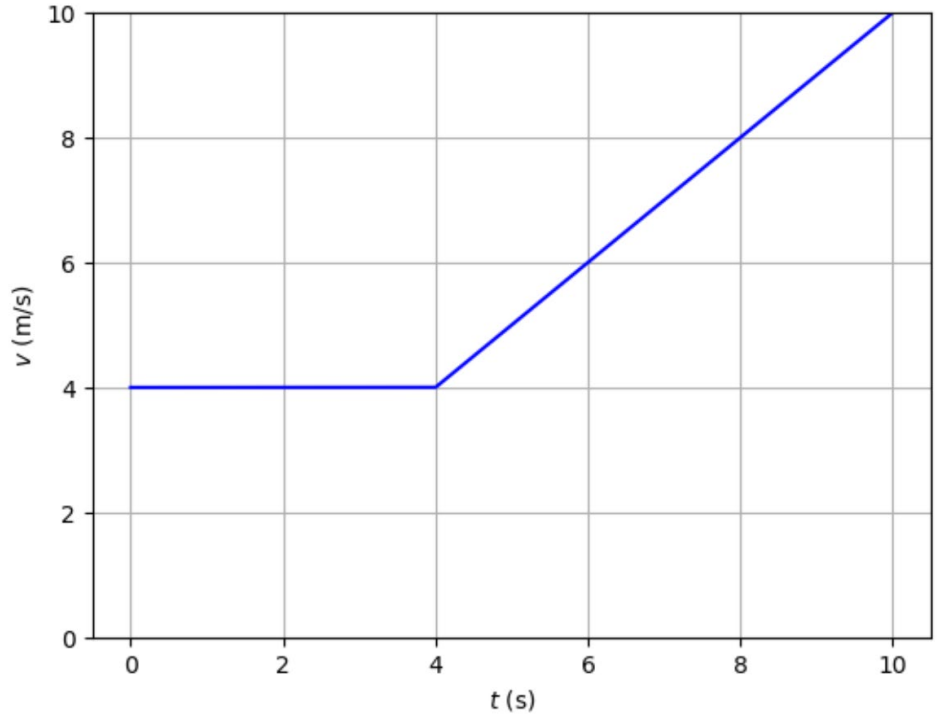
Question 2.

A reckless driver veers off the road with a speed of 220 km/h onto a soft plowed field. The car comes to a stop 4.60 seconds after the first contact with the ground. Assuming the acceleration is constant, how far does the car travel during this time period?

A) 70.8 m
B) 103. m
C) 141. m
D) 195. m
E) 253. m
F) 281. m
G) 379. m
H) 506. m
I) 708. m
J) 1.01 km
K) Don't know

Question 3.

The figure below shows the velocity of an object as a function of time. At time $t = 0$ s, the object is at position, $x = 10.0$ m.

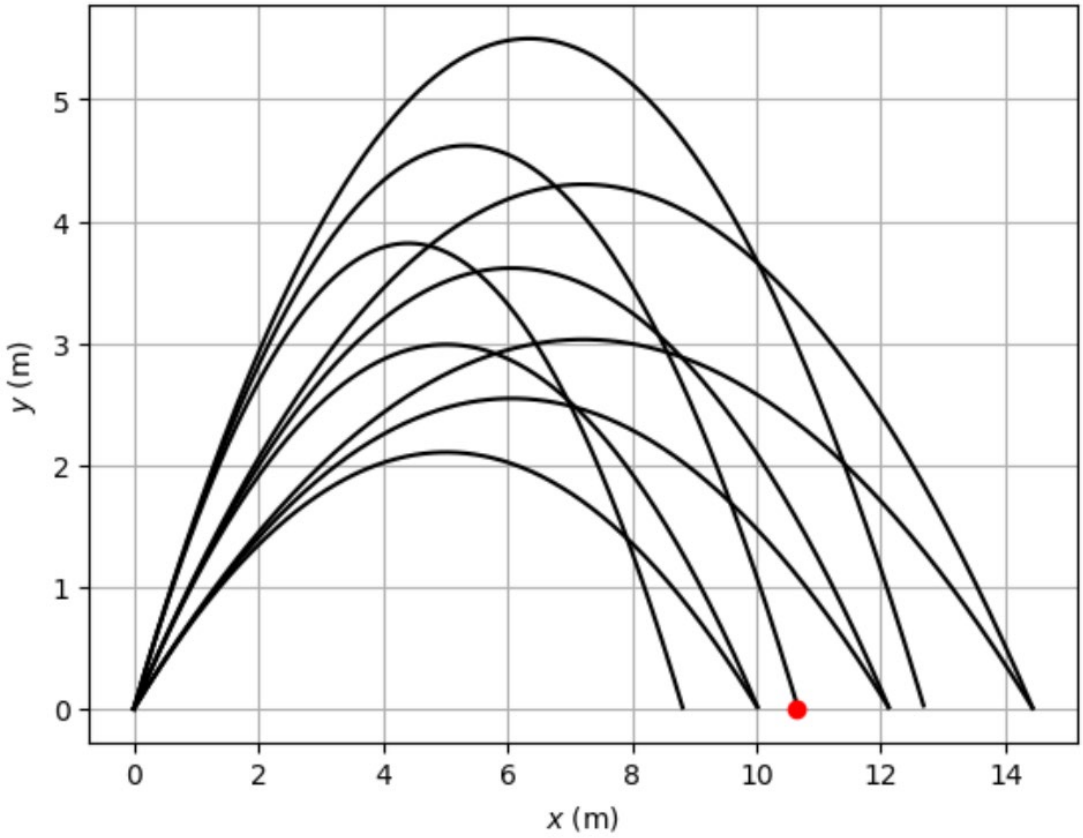


What is the position, x, of the object at time, $t = 10$ s?

A) $x = 30.0$ m
B) $x = 33.0$ m
C) $x = 38.0$ m
D) $x = 45.0$ m
E) $x = 47.0$ m
F) $x = 51.0$ m
G) $x = 58.0$ m
H) $x = 60.0$ m
I) $x = 68.0$ m
J) Don't know

Question 4.

The figure below illustrates projectile motions without air resistance. The initial velocity is 10 m/s, 11 m/s, or 12 m/s, and the launch angle is 40°, 50°, or 60°.



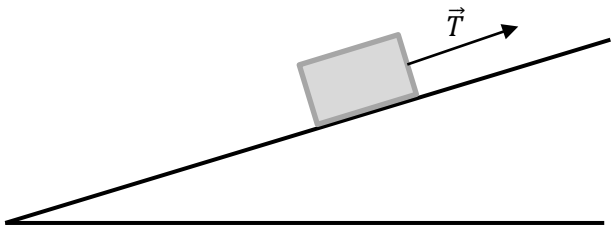
One of the shown projectiles point of impact is marked with a red circle.

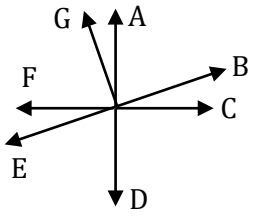
What is the initial velocity and launch angle of this projectile?

A) 10 m/s and 40°
B) 10 m/s and 50°
C) 10 m/s and 60°
D) 11 m/s and 40°
E) 11 m/s and 50°
F) 11 m/s and 60°
G) 12 m/s and 40°
H) 12 m/s and 50°
I) 12 m/s and 60°
J) Don’t know

Question 5.

A box is being pulled up a smooth inclined plane with a constant force, $\vec{T}$.





Which of the displayed forces (A-G) should be included in a force diagram for the box?

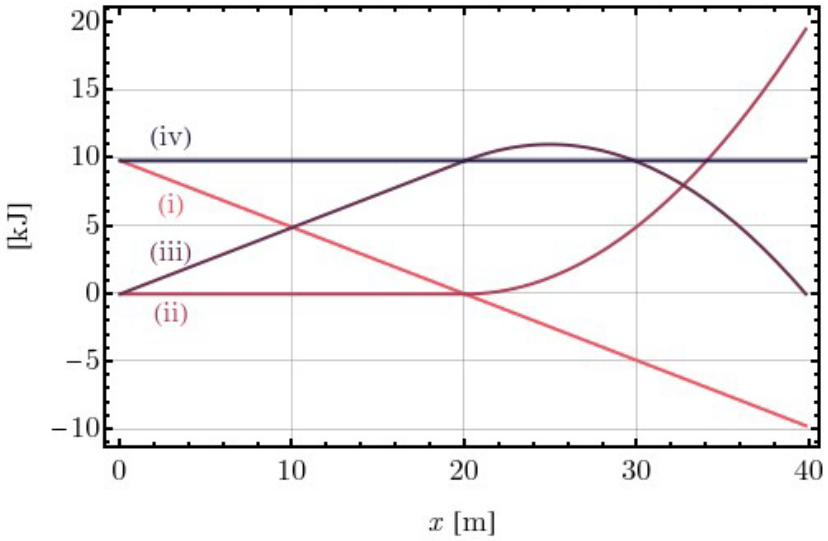
A) A
B) B
C) C
D) D
E) E
F) F
G) G
H) Don't know

Question 6.

A ski jumper with a mass of 95.3 kg including skis and clothing starts their jump at rest from the top of a ski jump hill and lands 130 meters below with a velocity of 28.0 m/s at impact. How much thermal energy, E_v has been generated by air resistance and sliding friction in the ski jumper's movement up to the moment of impact? The acceleration due to gravity can be set to g=9.81 m/s^2 on the ski jump hill.

A) E_v = 37.4 kJ
B) E_v = 54.6 kJ
C) E_v = 84.2 kJ
D) E_v = 98.7 kJ
E) E_v = 121. kJ
F) E_v = 159. kJ
G) E_v = 178. kJ
H) Don’t know

Question 7.



A bungee jumper is connected to a bridge by an elastic rope. The unstretched length of the rope is $l = 20$ m. The jumper lets herself fall from the bridge and is in free fall until she has fallen a distance l, after which the rope begins to stretch and slows the fall. Air resistance and friction can be ignored.

The figure shows different energies as a function of the fallen distance x from the bridge (positive downward) from the start of the fall until the lowest point reached by the bungee jumper.

Which energies can the four curves (i), (ii), (iii), and (iv) represent?

A) (i) represents gravitational potential energy
B) (ii) represents gravitational potential energy
C) (iii) represents gravitational potential energy
D) (i) represents elastic potential energy
E) (ii) represents elastic potential energy
F) (iii) represents elastic potential energy
G) (ii) represents kinetic energy
H) (iii) represents kinetic energy
I) (iv) represents kinetic energy
J) (ii) represents total mechanical energy.
K) (iii) represents total mechanical energy.
L) (iv) represents total mechanical energy.
M) Don't know.

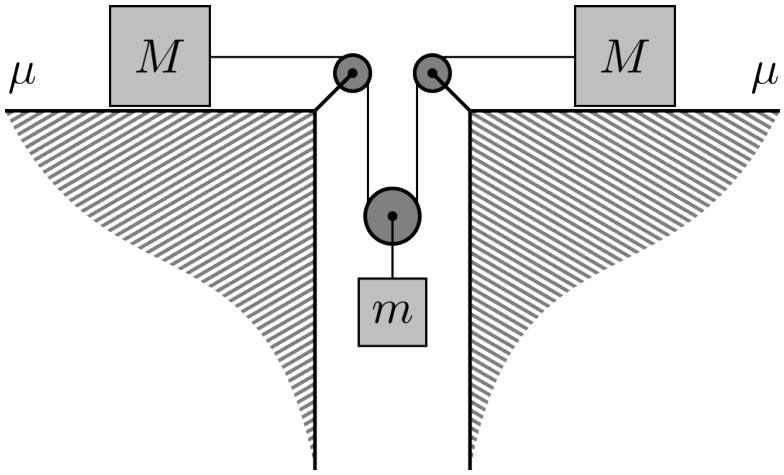
Question 8.

A skier moves with constant velocity down a hill with a constant inclination of 21.3 degrees relative to the horizontal. The skier's mass including skis and other equipment is 100. kg. The kinematic friction coefficient between snow and skis is 0.100. The acceleration due to gravity can be set to g=9.81 m/s^2.

What is the magnitude of the force F_l exerted by air resistance on the skier?

A) F_l =113. N
B) F_l =118. N
C) F_l =258. N
D) F_l =265. N
E) F_l =334. N
F) F_l =345. N
G) F_l =701. N
H) F_l =723. N
I) F_l =883. N
J) F_l =903. N
K) Don’t know

Question 9.



Two identical boxes with mass $M = 10$ kg are connected by massless and frictionless pulleys with a rope, on which hangs a mass $m = 2.0$ kg, as shown in the figure. The surface beneath the boxes is rough, with a kinetic friction coefficient μ.

The boxes slide, and the mass moves downward at a constant velocity. What is the friction coefficient μ?

A) 10
B) 5.0
C) 1.4
D) 0.90
E) 0.50
F) 0.20
G) 0.10
H) Don't know

Question 10.

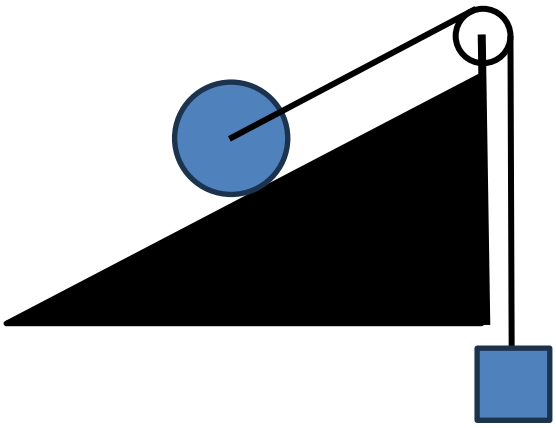
A planetary scientist from DTU believes to have discovered a new planet in a distant planetary system. The planet has a mass $m = 5.97 \cdot 10^{24}$ kg and is in a circular orbit around a star. The orbital period is 1039 days.

The star has a mass $M = 2.43 \cdot 10^{29}$ kg.

What is the distance from the planet to the star?

A) $5.27 \cdot 10^6$ km
B) $9.62 \cdot 10^6$ km
C) $11.5 \cdot 10^6$ km
D) $32.6 \cdot 10^6$ km
E) $50.0 \cdot 10^6$ km
F) $74.3 \cdot 10^6$ km
G) $126 \cdot 10^6$ km
H) $149 \cdot 10^6$ km
I) $188 \cdot 10^6$ km
J) $275 \cdot 10^6$ km
K) Don't know

Question 11.



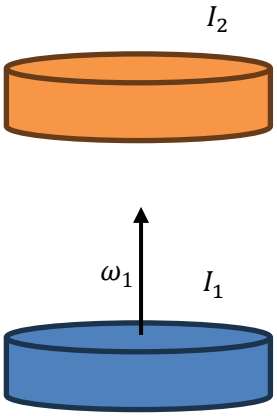
A block with mass $m = 1.00$ kg hangs on a rope, which is connected over a massless, frictionless pulley to the axis of a solid cylinder rolling on an inclined plane. The inclined plane forms an angle $\theta = 30°$ with the horizontal. The cylinder has the same mass as the block and a radius $r = 8$ cm.

The block is now released from rest. What is the speed of the block when it has fallen a distance d= 10 cm?

A) $0.42 \frac{\mathrm{m}}{\mathrm{s}}$
B) $0.57 \frac{\mathrm{m}}{\mathrm{s}}$
C) $0.63 \frac{\mathrm{m}}{\mathrm{s}}$
D) $0.68 \frac{\mathrm{m}}{\mathrm{s}}$
E) $0.71 \frac{\mathrm{m}}{\mathrm{s}}$
F) $0.77 \frac{\mathrm{m}}{\mathrm{s}}$
G) $0.81 \frac{\mathrm{m}}{\mathrm{s}}$
H) $1.26 \frac{\mathrm{m}}{\mathrm{s}}$
I) Don't know

Question 12.

A homogeneous disk with a moment of inertia, I_1, is placed on a horizontal, smooth surface. The disk rotates with an angular velocity, ω_1.



Another disk with a moment of inertia, I_2, which is not rotating, falls onto the first disk. After a short period of time, the two disks rotate with the common angular velocity, $\omega_2 = \frac{3}{5}\omega_1$.

What is the moment of inertia, I_2?

A) $I_2 = \frac{1}{2}I_1$
B) $I_2 = \frac{1}{3}I_1$
C) $I_2 = \frac{1}{4}I_1$
D) $I_2 = \frac{2}{3}I_1$
E) $I_2 = \frac{3}{4}I_1$
F) $I_2 = \frac{2}{5}I_1$
G) $I_2 = \frac{3}{5}I_1$
H) $I_2 = \frac{4}{5}I_1$
I) $I_2 = \frac{5}{3}I_1$
J) Don't know

Question 13.

A water droplet weighing 8.0 mg falls from a cloud 1.0 km above and is slowed down by air friction. We assume a constant air resistance affecting the raindrop of $1.4 \cdot 10^{-4}$ N.

How much does the raindrop warm up due to friction?

A) 0.5 K
B) 1.1 K
C) 2.9 K
D) 3.1 K
E) 3.4 K
F) 4.2 K
G) 6.3 K
H) 10.7 K
I) Don't know

Question 14.

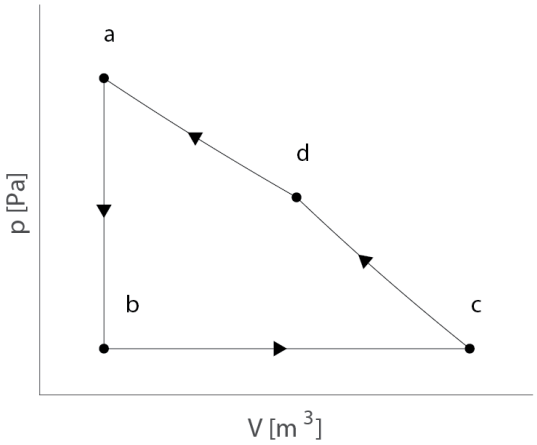
A cylinder with a piston is filled with an ideal gas at 20°C. You now slowly push the piston in, so the temperature of the gas does not change. In this process, 560 J of work is done on the gas.

What is the change in entropy of the gas in this process?

A) $1.91\ \mathrm{J/K}$
B) $-1.91\ \mathrm{J/K}$
C) $8.6\ \mathrm{J/K}$
D) $-8.6\ \mathrm{J/K}$
E) $9.9\ \mathrm{J/K}$
F) $-9.9\ \mathrm{J/K}$
G) $28.0\ \mathrm{J/K}$
H) $-28.0\ \mathrm{J/K}$
I) Don’t know

Question 15.

A thermodynamic cycle proceeds as shown in the diagram to the right. The gas is a monoatomic ideal gas with 1.3 mol. Process *cd* is adiabatic, and process *da* is isothermal.



During which processes is heat added/removed?

A) For *ab* is $Q > 0$.
B) For *ab* is $Q < 0$.
C) For *bc* is $Q > 0$.
D) For *bc* is $Q < 0$.
E) For *cd* is $Q > 0$.
F) For *cd* is $Q < 0$.
G) For *da* is $Q > 0$.
H) For *da* is $Q < 0$.
I) Don't know

Question 16. [Continuation of the previous question]

At point a, the volume is $V_a = 1.10$ L and the temperature is $T_a = 77.0$ °C. At point b, the temperature is $T_b = 17.0$ °C, and at point c, $T_c = 62.0$ °C. What is the volume at point c?

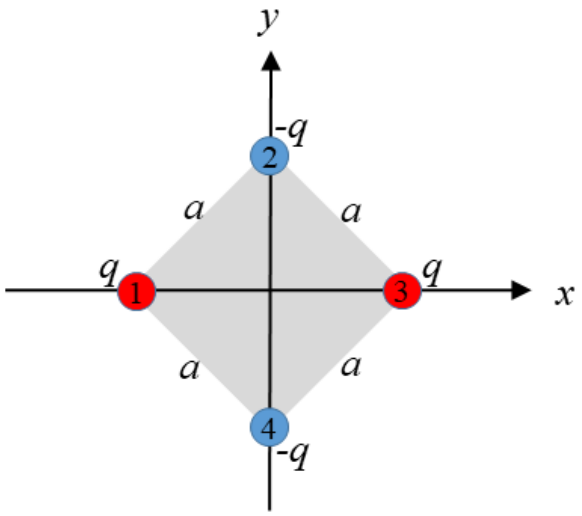
A) 1.38 L
B) 1.27 L
C) 3.95 L
D) 4.01 L
E) 5.17 L
F) 6.45 L
G) 7.30 L
H) 8.16 L
I) Don't know

Question 17. [Continuation of the previous question]

What is the volume at point *d*?

A) 1.16 L
B) 2.27 L
C) 1.19 L
D) 2.36 L
E) 0.92 L
F) 1.14 L
G) 2.54 L
H) 1.23 L
I) 3.41 L
J) Don't know

Question 18.



Four equally large point charges are placed in the corners of a square in the *x*-*y* plane, as shown in the figure to the right. The two red point charges on the *x*-axis each have the positive charge *q*, and the two blue point charges on the *y*-axis each have the negative charge –*q*.

The zero value for the electrostatic potential energy is chosen to be infinitely far away.

Which of the following statements are correct:

A) The electric field is zero in the point (0,0)
B) The electric field is zero for all points at the *x*-axis
C) The electric field is zero for all points at the *y*-axis
D) The net electrostatic force on charge 1 is directed parallel to the *x*-axis (towards the right)
E) The net electrostatic force on charge 2 is directed parallel to the *y*-axis (straight up)
F) The potential energy of the charge configuration is positive
G) The potential energy of the charge configuration is zero
H) Don't know

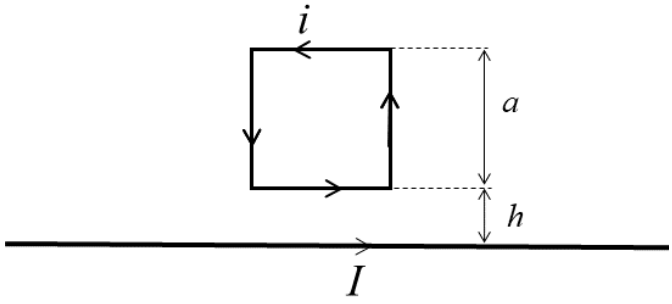
Question 19.

In a square loop with side $a = 30.0$ cm runs the current $i = 3.00$ A.

In a long straight wire runs the current $I = 7.00$ A.

The current loop is placed distance $h = 10.0$ cm from the wire, as shown in the figure. The square loop is placed above the wire in the plane of the paper with two sides parallel to the wire and two sides perpendicular to the wire.

What is the net force on the current loop?



A) $1.26 \cdot 10^{-5}$ N, down
B) $1.89 \cdot 10^{-6}$ N, down
C) $3.15 \cdot 10^{-6}$ N, down
D) $9.45 \cdot 10^{-6}$ N, down
E) $1.26 \cdot 10^{-5}$ N, up
F) $1.89 \cdot 10^{-6}$ N, up
G) $3.15 \cdot 10^{-6}$ N, up
H) $9.45 \cdot 10^{-6}$ N, up
I) Don't' know

Question 20.

A Chlor-ion (Cl^-) moves with the speed $v = 2.76 \cdot 10^4$ m/s into an area of 5 cm × 10 cm with a homogenous magnetic field of 1 T directed perpendicular to the area as shown in the figure (the magnetic field points into the plane of the paper).

The Chlor-ion has the charge $e = -1.602 \cdot 10^{-19}$ C and the mass 35 AMU. 1 AMU = $1.661 \cdot 10^{-27}$ kg.

At which point will the Chlor-ion leave the area again?

A) In point A
B) In point B
C) In point C
D) In point D
E) In point E
F) In point F
G) In point G
H) In point H
I) Don't know