Technical University of Denmark

Written examination, Saturday, December 14, 2024

Course name Physics (Polytechnical Foundation)

Course number. 10063

Duration: 4 hours

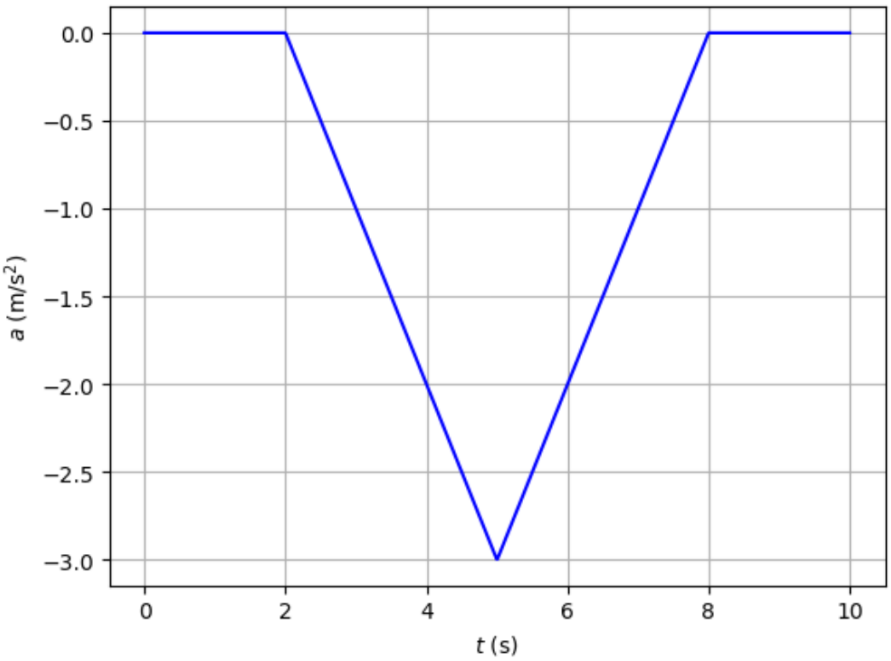
Permitted aids: All aids are allowed, except internet access.

"Weighting": The answers will be assessed as a whole.

The set consists of 26 multiple-choice questions. Incorrect answers do not count negatively in the assessment. Some questions have one correct answer, while others require a combination of multiple correct options. Partially correct answers will contribute positively to the evaluation.

Question 1.

A car is driving at time $t = 0$ s with a velocity v on a straight road. At time $t = 2$ s, the car begins to brake, and at time $t = 8$ s, the car comes to a complete stop. The car's acceleration is shown in the figure below.



What was the car's velocity v at $t = 0$ s?

A) $v = -18$ m/s
B) $v = -12$ m/s
C) $v = -9$ m/s
D) $v = -6$ m/s
E) $v = -3$ m/s
F) $v = 3$ m/s
G) $v = 6$ m/s
H) $v = 9$ m/s
I) $v = 12$ m/s
J) $v = 18$ m/s

Question 2.

Two objects travel the same distance, $L = 10.00 \pm 0.10$ m. Both objects move at a constant velocity. The first object travels the distance in $t = 2$ s, while the second object travels the distance in $t = 5$ s. The times have been determined with high precision, so their uncertainties can be ignored.

What is the uncertainty on the average velocity of the two objects?

A) $\delta\bar{v} = 0.020$ s
B) $\delta\bar{v} = 0.021$ s
C) $\delta\bar{v} = 0.025$ s
D) $\delta\bar{v} = 0.027$ s
E) $\delta\bar{v} = 0.030$ s
F) $\delta\bar{v} = 0.035$ s
G) $\delta\bar{v} = 0.050$ s
H) $\delta\bar{v} = 0.054$ s
I) $\delta\bar{v} = 0.069$ s
J) $\delta\bar{v} = 0.075$ s

Question 3.

To determine the structure of a model that includes speed, v, and gravitational acceleration, g, among the independent variables, one aims to identify the natural time and length scales.

Which of the following expressions are natural scales for time or length?

A) $\frac{1}{vg}$
B) $\frac{g}{v}$
C) $\frac{g^2}{v}$
D) $\frac{v}{g}$
E) gv
F) vg^2
G) gv^2
H) $\frac{v^2}{g}$

Question 4.

A ruler with a length of 1.00 m oscillates with an amplitude of 45.0°. The ruler is fixed to a horizontal axis of rotation at one end. Use the gravitational acceleration $g = 9.82\ \mathrm{m/s^2}$.

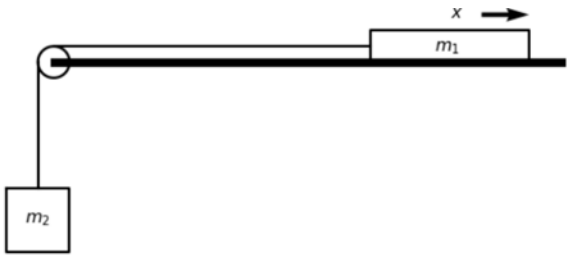
The oscillations of the ruler can be described by $\frac{d\theta}{dt} = \omega$ and $\frac{d\omega}{dt} = -\frac{3g}{2l}\sin\theta$.

What is the oscillation period of the ruler?

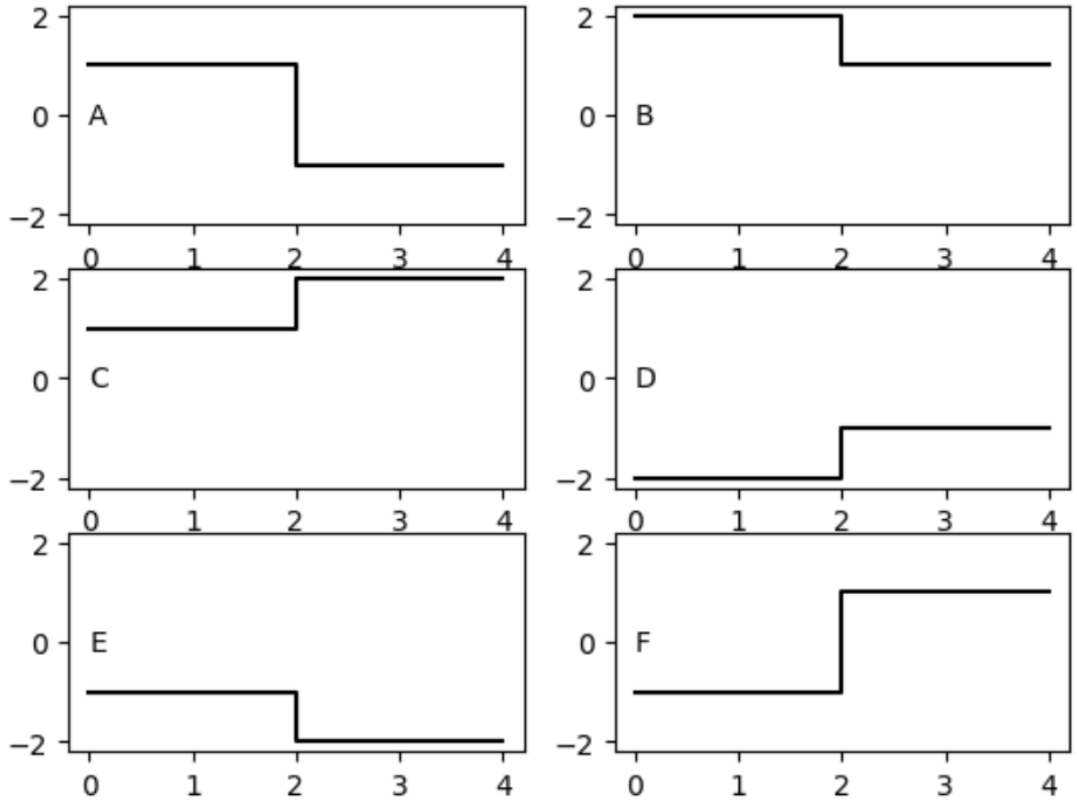
A) $T = 1.40$ s
B) $T = 2.00$ s
C) $T = 1.22$ s
D) $T = 3.35$ s
E) $T = 1.64$ s
F) $T = 2.80$ s
G) $T = 1.70$ s
H) $T = 3.40$ s
I) $T = 4.37$ s

Question 5.

A block with mass m_1 is placed on a horizontal table. The table has a rough surface. Initially, the block moves to the right, and after some time, it begins to move to the left. The block remains on the table throughout the motion. The block is connected via a string, which passes over a massless, frictionless pulley, to a hanging mass m_2.



The figure below shows six different graphs of acceleration as a function of time. The acceleration is considered positive to the right.

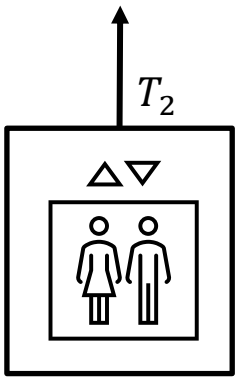


Which graph does best describe the block's acceleration?

A) A
B) B
C) C
D) D
E) E
F) F

Question 6.

An elevator accelerates upwards with acceleration a. The elevator has a mass M, and inside the elevator, there are two people, each with a mass m. The magnitude of the tension pulling the elevator upwards is T_2.



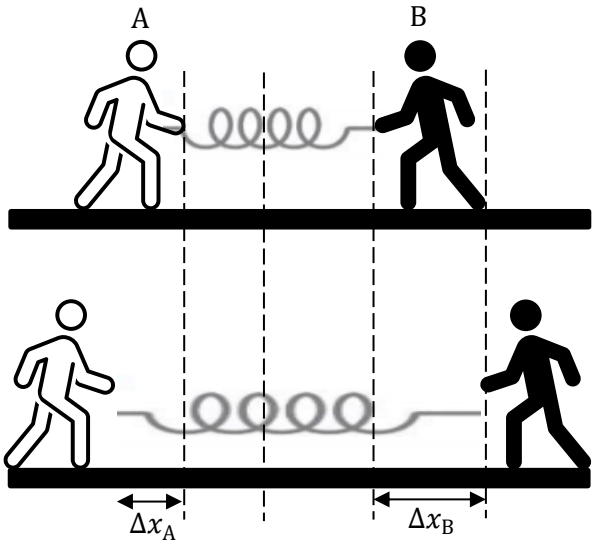
When one person accelerates with the elevator at the same acceleration a, the magnitude of the tension is T_1.

What is $T_2 - T_1$?

A) $T_2 - T_1 = mg$
B) $T_2 - T_1 = ma$
C) $T_2 - T_1 = 2mg$
D) $T_2 - T_1 = 2ma$
E) $T_2 - T_1 = m(a - g)$
F) $T_2 - T_1 = m(g - a)$
G) $T_2 - T_1 = m(a + g)$
H) $T_2 - T_1 = 2m(a - g)$
I) $T_2 - T_1 = 2m(g - a)$
J) $T_2 - T_1 = 2m(a + g)$

Question 7.

Two people, A and B, hold each end of a horizontal spring. In the initial situation (shown at the top of the figure below), the spring force is zero. The spring has a spring constant k. Person A now moves a distance $\Delta x_{\mathrm{A}} > 0$, and simultaneously person B moves a distance $\Delta x_{\mathrm{B}} > 0$. A and B are now stationary.



In the final situation (shown at the bottom of the figure above), it holds that:

A) A is affected by a force with a magnitude of $k\Delta x_{\mathrm{A}}$.
B) B is affected by a force with a magnitude of $k\Delta x_{\mathrm{A}}$.
C) A is affected by a force with a magnitude of $k\Delta x_{\mathrm{B}}$.
D) B is affected by a force with a magnitude of $k\Delta x_{\mathrm{B}}$.
E) A is affected by a force with a magnitude of $k(\Delta x_{\mathrm{A}} + \Delta x_{\mathrm{B}})$.
F) B is affected by a force with a magnitude of $k(\Delta x_{\mathrm{A}} + \Delta x_{\mathrm{B}})$.

Question 8.

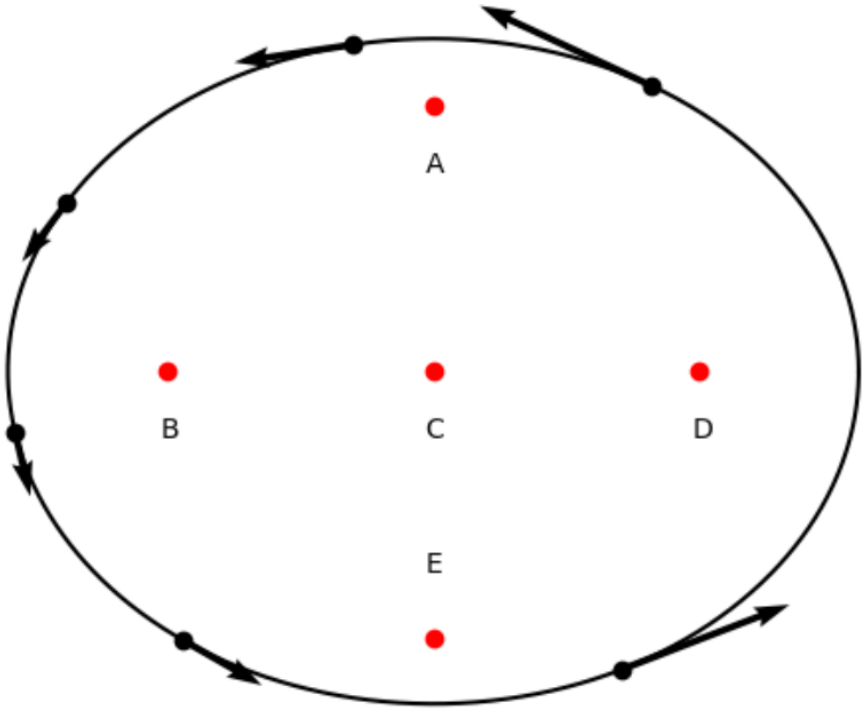
A spaceship with a mass of $m = 7500$ kg and a speed of 10 km/h is to dock with a stationary space station with a mass of $M = 30000$ kg.

What is the combined speed of the spaceship and the space station after docking?

A) They move at 5 km/h
B) They move at 10 km/h
C) They move at 15 km/h
D) They move at 1 km/h
E) They move at 2 km/h
F) They move at 2.5 km/h
G) They do not move

Question 9.

A satellite moves around the Earth in an elliptical orbit. The satellite's position and velocity are shown in the figure below at six different points in time.

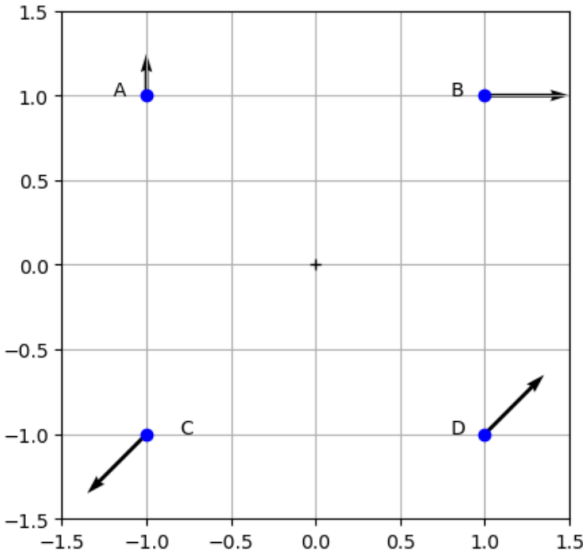


At which of the shown positions A, B, C, D, or E is the Earth located?

A) A
B) B
C) C
D) D
E) E
F) A or E
G) B or D

Question 10.

Four identical particles are moving in a plane. At a given moment, their velocity vectors are as shown in the figure. The speed at B, C, and D is twice the speed at A.



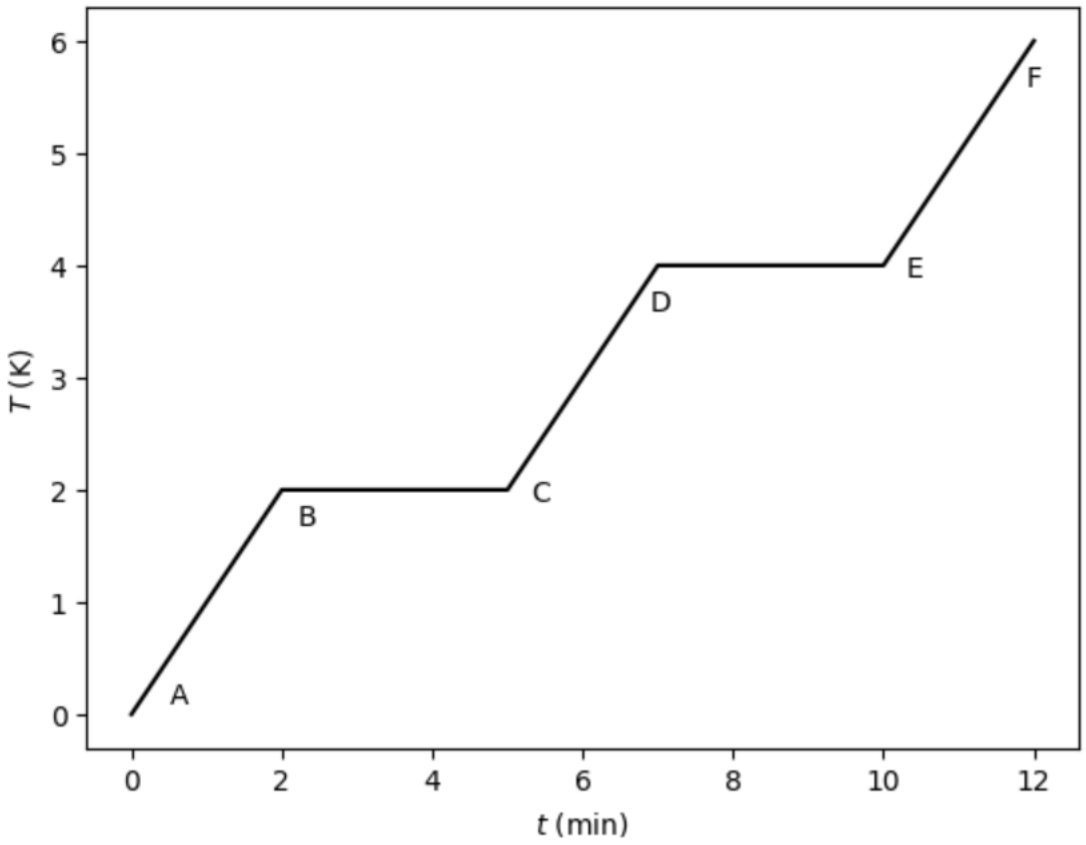
The magnitudes of the particles' angular momenta with respect to the origin (marked with + in the figure) are L_A, L_B, L_C, L_D .

Which inequalities apply to the magnitudes of the angular momenta?

A) $L_A > L_B$
B) $L_A < L_B$
C) $L_A > L_C$
D) $L_A < L_C$
E) $L_A > L_D$
F) $L_A < L_D$
G) $L_B > L_C$
H) $L_B < L_C$
I) $L_B > L_D$
J) $L_B < L_D$
K) $L_C > L_D$
L) $L_C < L_D$

Question 11.

Heat is supplied at a constant rate to a homogeneous substance. The substance is in solid form at the initial time $t = 0$ min. The temperature of the substance as a function of time is shown in the figure below.



When is the substance in pure liquid form?

A) AB
B) BC
C) CD
D) DE
E) EF

Question 12.

An ideal gas with 0.0200 mol has a pressure of 1.35 atm, and a volume of 3.20 L. What is the temperature of the gas?

A) 2633 K
B) 26.00 K
C) 168.8 K
D) 1392 K
E) 240.4 K
F) 494.7 K
G) 4119 K
H) 3477 K

Question 13.

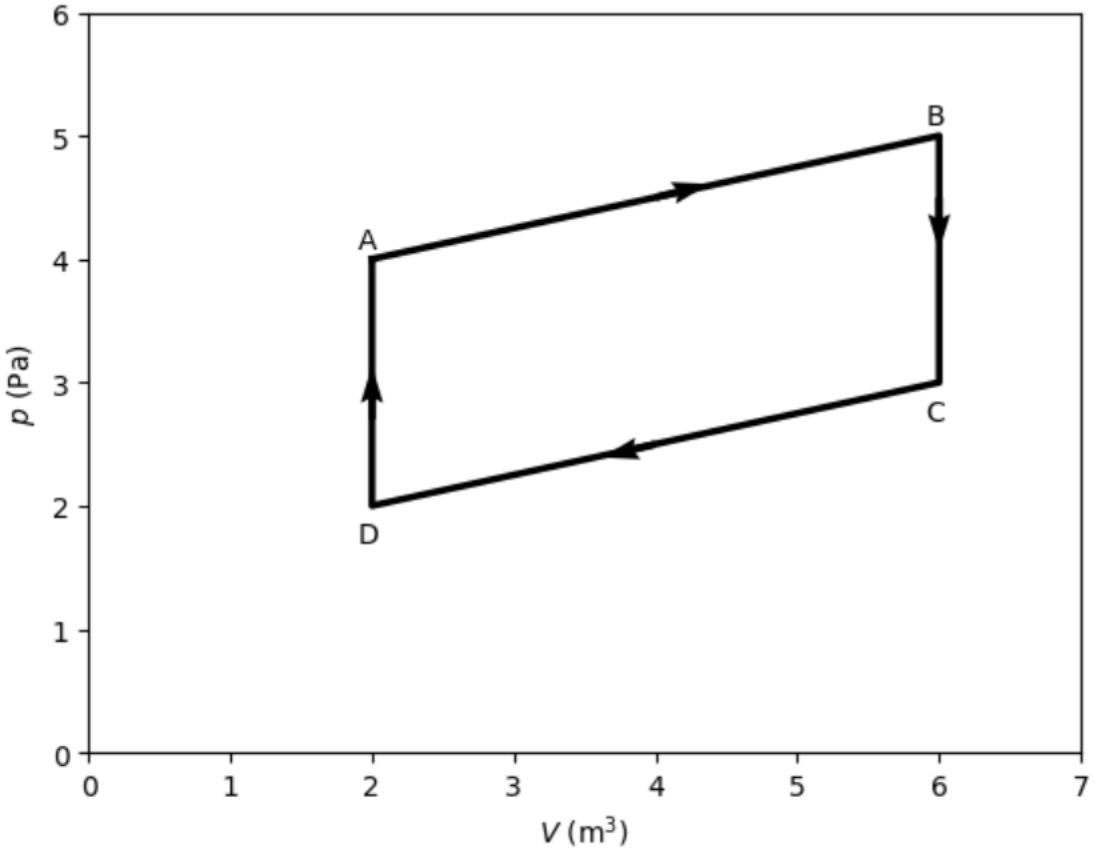
A typical freezer cools to -18 °C from room temperature, 23 °C. The freezer uses 60 W and cools at 192 W.

How efficient is it compared to a Carnot refrigerator?

A) 23 %
B) 66 %
C) 69 %
D) 75 %
E) 46 %
F) 90 %
G) 51 %
H) 92 %

Question 14.

Below is a *pV*-diagram for an ideal gas undergoing a cyclic process.



Select the correct statements.

A) During AB the gas performs work $W_{\mathrm{AB}} > 0$
B) During AB work $W_{\mathrm{AB}} < 0$ is done on the gas
C) During BC heat $Q_{\mathrm{BC}} > 0$ is added to the gas
D) During BC the gas releases heat $Q_{\mathrm{BC}} < 0$
E) During CD the gas performs work $W_{\mathrm{CD}} > 0$
F) During CD work $W_{\mathrm{CD}} < 0$ is done on the gas
G) During DA heat $Q_{\mathrm{DA}} > 0$ is added to the gas
H) During DA the gas releases heat $Q_{\mathrm{DA}} < 0$

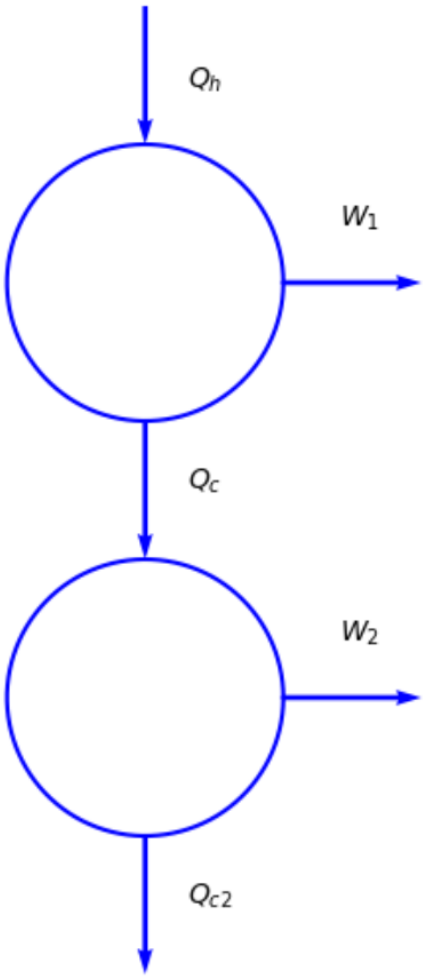
Question 15.

A diatomic ideal gas of 0.78 mol at a pressure of 1.5×10^3 Pa is cooled at constant pressure from 74°C until it reaches a volume of 0.85 m^3. How much heat is added to the gas?

A) 1.9 kJ
B) 2.8 kJ
C) −3.9 kJ
D) −3.4 kJ
E) −2.1 kJ
F) 4.4 kJ
G) 2.6 kJ
H) −1.5 kJ

Question 16.

A combined engine consists of two heat engines, as shown in the figure to the right. Heat is supplied in the form of Q_h , and two works are extracted, W_1 and W_2.



It is stated that the magnitude of Q_h is 1000 J, the magnitude of Q_c is 500 J and the magnitude of Q_{c2} is 300 J.

What is the efficiency of the combined engine?

A) $e = \frac{1}{2}$
B) $e = \frac{2}{7}$
C) $e = \frac{3}{7}$
D) $e = \frac{7}{10}$
E) $e = \frac{3}{10}$
F) $e = \frac{1}{4}$
G) $e = \frac{2}{5}$
H) $e = \frac{1}{10}$
I) $e = \frac{2}{3}$
J) $e = \frac{9}{10}$

Question 17.

Your refrigerator has broken down, but you're a Do-It-Yourself (DIY) enthusiast. You find your old heat pump in the shed and decide to connect it to your refrigerator as a temporary solution.

If your heat pump has a coefficient of performance K_P of 4.3, what can you expect the coefficient of performance K_R to be for your Do-It-Yourself refrigerator?

A) $K_R = 4.3$
B) $K_R = 3.5$
C) $K_R = 2.0$
D) $K_R = 5.3$
E) $K_R = 3.3$
F) $K_R = 1.3$
G) $K_R = 2.3$
H) $K_R = 4.0$

Question 18.

An ideal gas in a container is slowly compressed using a piston. The temperature does not change. The surroundings can be considered a reservoir. The universe consists of the surroundings and the system. How does the entropy change?

A) The entropy of the gas increases.
B) The entropy of the gas is constant.
C) The entropy of the gas decreases.
D) The entropy of the universe increases.
E) The entropy of the universe is constant.
F) The entropy of the universe decreases.

Question 19.

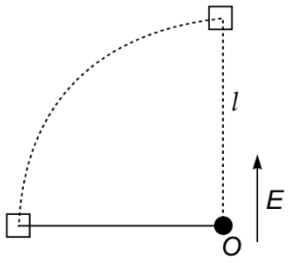
Two electrical conductors have circular cross-sections and are made of the same material. Conductor A is 10 km long with a diameter of 1 cm, conductor B is 50 km long with a diameter of 2 cm.

What is the ratio of the resistances of the two conductors, R_A and R_B ?

A) $\frac{R_A}{R_B} = \frac{1}{20}$
B) $\frac{R_A}{R_B} = \frac{1}{10}$
C) $\frac{R_A}{R_B} = \frac{1}{5}$
D) $\frac{R_A}{R_B} = \frac{2}{5}$
E) $\frac{R_A}{R_B} = \frac{4}{5}$
F) $\frac{R_A}{R_B} = \frac{5}{4}$
G) $\frac{R_A}{R_B} = \frac{5}{2}$
H) $\frac{R_A}{R_B} = 5$
I) $\frac{R_A}{R_B} = 10$
J) $\frac{R_A}{R_B} = 20$

Question 20.

A block with mass m and electric charge $q > 0$ is placed on a horizontal, frictionless table. The situation is shown in the figure to the right, viewed from above. The block is attached to a point O with a string. The string has a length l. A constant electric field is then applied, pointing as shown in the figure. The block starts in the position to the left (the string is shown as a solid line). The dashed straight line indicates the position of the string when the block is first parallel to the electric field. The curved dashed line shows the path the block follows between the two positions.



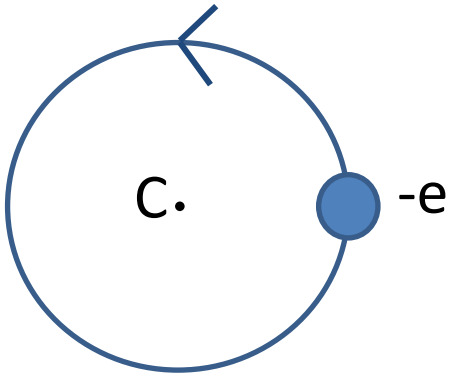
What is the magnitude of the string tension T when the string is first parallel to the electric field?

A) $T = qE$
B) $T = 2qE$
C) $T = 3qE$
D) $T = 4qE$
E) $T = \frac{q}{2}E$
F) $T = \frac{q}{3}E$
G) $T = \frac{2q}{3}E$
H) $T = \frac{q}{4}E$

Question 21.

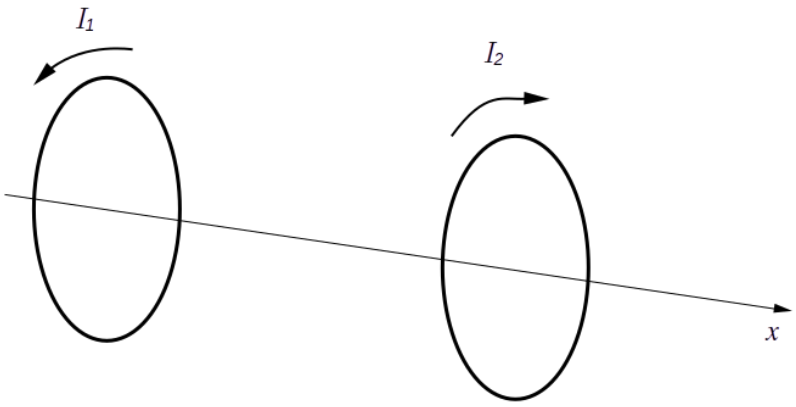
An electron performs uniform circular motion around a center C, as shown in the figure.

Which of the following fields could cause the motion shown?



A) Electric field from fixed negative point charge in C
B) Electric field from fixed positive point charge in C
C) Electric field from positive infinite planar charge distribution through C
D) Homogenous electric field out of the plane
E) Homogenous electric field into the plane
F) Homogenous magnetic field out of the plane
G) Homogenous magnetic field into the plane
H) Homogenous magnetic field directed towards left
I) Homogenous magnetic field directed towards right

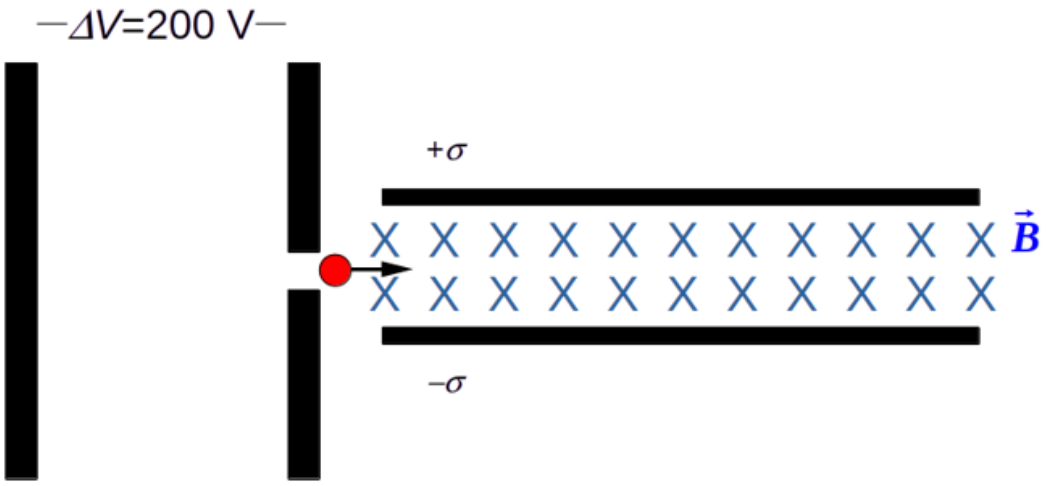
Question 22.



Two solenoids with the same radius has the *x*-axis as common center line, and they carry the currents I_1 and I_2, see the figure. The arrow indicates the positive *x*-direction. What can we state about the total magnetic field from the two solenoids in the point at the x-axis that is exactly in the middle between the solenoids?

A) The total field is directed in the positive *x*-direction
B) The total field is directed in the negative *x*-direction
C) The total field is perpendicular to the *x*-axis
D) The total field is zero
E) The direction of the total field depends on the ratio between I_1 and I_2

Question 23.



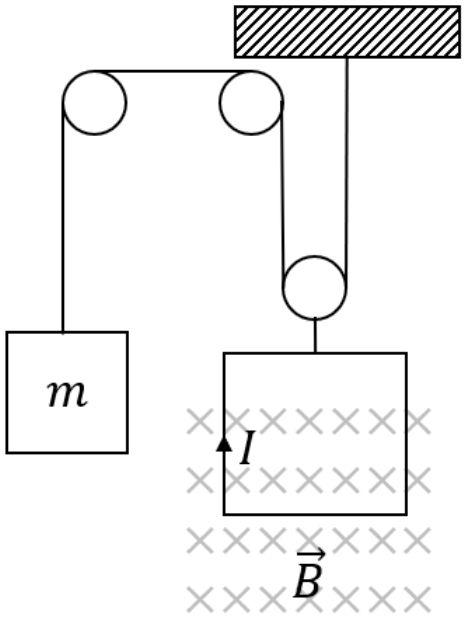
A proton with the charge $+e$ (the elementary charge) and the mass $m=1.67\cdot10^{-27}$ kg is being accelerated from rest over a potential drop of 200 V and then it moves in between two homogeneous planar charge distributions with charge density $\pm1.00\cdot10^{-6}$ C/m^2. The charge distributions can be assumed to cover an infinite area so edge fields can be neglected. In between the charge distributions there is also a homogenous magnetic field, B, that is directed into the plane as shown in the figure.

What magnitude should the B-field have for the proton to move in a straight line between the planes?

A) B=0.153 T
B) B=0.288 T
C) B=0.408 T
D) B=0.577 T
E) B=0.815 T
F) B=0.974 T
G) B=1.06 T

Question 24.

A block with mass m is fixed to the ceiling with a string that goes via three massless, frictionless pulleys. A square current loop with side length l is hanging from the lower pulley with the sides being horizontal and vertical. The loop carries a current I. The lower part of the current loop is placed in a homogenous magnetic field of magnitude B directed into the plane of the screen.

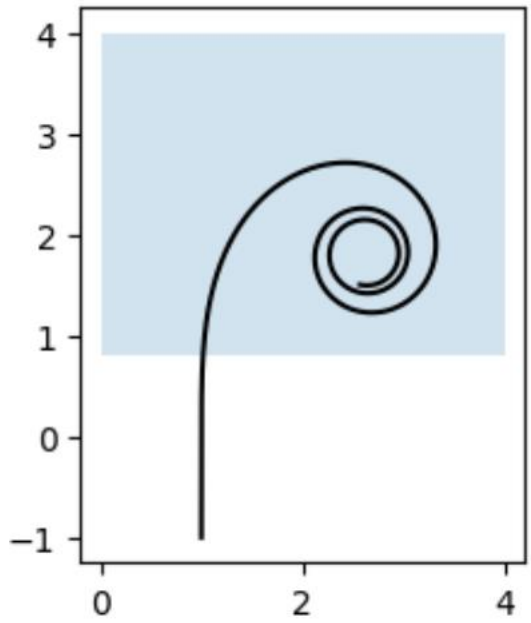


What should the magnitude of the current I be so that the mass is in equilibrium?

A) $I = \frac{mg}{Bl}$
B) $I = \frac{2mg}{Bl}$
C) $I = \frac{mg}{2Bl}$
D) $I = \frac{mgl}{B}$
E) $I = \frac{2mgl}{B}$
F) $I = \frac{mgl}{2B}$

Question 25.

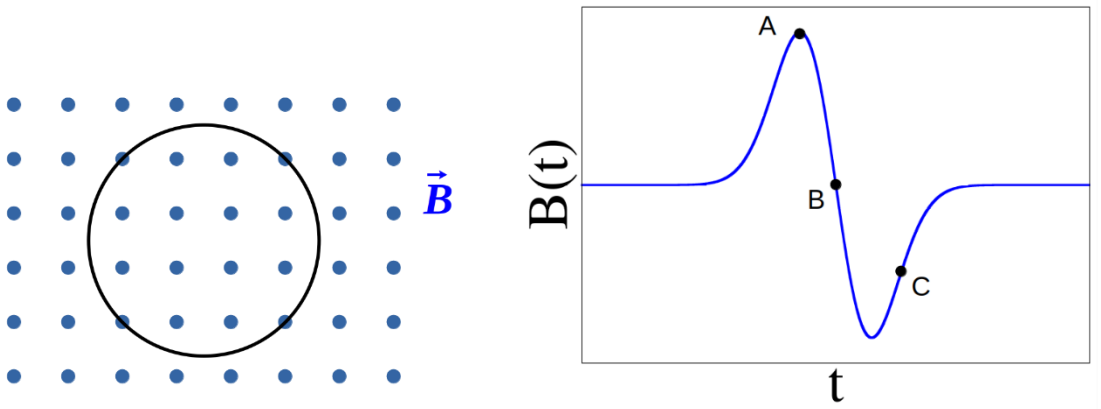
An electron is sent off with direction up. In the shaded area, there is a time-varying magnetic field with constant direction. The trajectory of the electron has the shape of a spiral in the shaded area.



Choose the correct statements.

A) The direction of the magnetic field is up.
B) The direction of the magnetic field is down.
C) The direction of the magnetic field is out of the screen.
D) The direction of the magnetic field is into the screen.
E) The direction of the magnetic field is to the left.
F) The direction of the magnetic field is to the right.
G) The magnitude of the magnetic field is increasing with time.
H) The magnitude of the magnetic field is decreasing with time.

Question 26.



A circular current loop is placed in a homogenous magnetic field, *B(t)*, that is perpendicular to the plane of your screen, as shown in the figure to the left. *B* is positive in the direction out of the screen's plane. The figure to the right shows *B* as a function of time *t*. It can be assumed that the resistance of the loop is large enough that the current at any time reflects the instant emf.

What can we state about the induced current in the loop at the three times marked A, B, and C?

A) The current runs clockwise at time A
B) The current runs anti-clockwise at time A
C) The current is zero at time A
D) The current runs clockwise at time B
E) The current runs anti-clockwise at time B
F) The current is zero at time B
G) The current runs clockwise at time C
H) The current runs anti-clockwise at time C
I) The current is zero at time C