DELFT UNIVERSITY OF TECHNOLOGY **Faculty of Aerospace Engineering**	TU Delft
Course: Physics (AE1241)	**Date:** Wednesday 19 April 2023, 13.30-16.30 h
Examiners: Dr.ir. M.I. Gerritsma, Dr. R. Merino Martinez and Dr. F. Yin	

- This exam consists of 4 open questions and 20 multiple-choice questions.
- For the multiple choice questions, mark the correct answer on the answer sheet with a black or blue pen.
- Only the calculator provided by the faculty is allowed. The use of extra material during this exam (books, notes, formula sheets, electronic storage, etc.) is FORBIDDEN.
- Put your full name and student number on your work. Do not leave the exam without handing in both answer sheets.
- A list of constants, tables and difficult equations is available at the end of this exam.

The first 4 questions are open questions. Please use the lined paper to answer these questions. Make sure you put your name and student number on all answer sheets that you hand in.

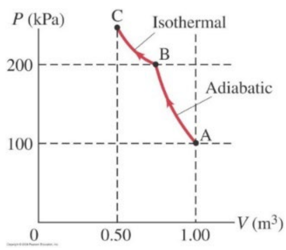
Open Question 1

(A) A certain turbofan engine emits a broadband sound level of 110 dB. What would be the sound level if four turbofan engines are present? (1 point)
(B) An aircraft equipped with these turbofan engines emits a tonal sound of 1800 Hz. The aircraft is moving towards an observer on the ground, who perceives a frequency of 2400 Hz because of the Doppler effect. What is the velocity of the aircraft in m/s? Take for the speed of sound 343 m/s. (2 points)
(C) If the aircraft flies at a Mach number of 2 and an observer on the ground perceives the shock wave 0.433 s after passing directly overhead the observer, at what altitude is the aircraft flying? Take for the speed of sound 343 m/s. (2 points)

Open Question 2

In the process of taking an ideal monatomic gas from state A to state C along the two steps (A to B and B to C) shown in the PV diagram. The temperature at the state A is 310 K.

(A) What is an isothermal process. (1 point)
(B) What an adiabatic process. (1 point)
(C) Determine the volume at the state B. (1 points)
(D) Calculate the work done through the whole process. (2 points)



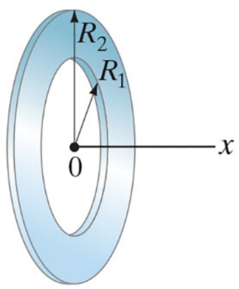
Open Question 3

An ice-cube tray containing 500 g of water at 15°C is placed into a freezer. The freezer uses 200 W of power. After 5 minutes, half of the water is frozen into ice at 0°C.

(A) Explain the working principle of a freezer. (1 point)
(B) Calculate the total amount of energy to be removed from the water described in the process above. (2 points)
(C) Calculate the coefficient of performance (COP) for the freezer. (1 point)
(D) Assuming the heat removed in step b is released into atmosphere at 20 ℃ and its temperature rise is insignificant. Calculate the entropy change of the environment. (1 point)

Open Question 4

A flat ring of inner radius R_1 and outer radius R_2 carries a net charge of $+Q$ distributed uniformly over the surface of the ring, see figure.



(A) Determine the electric potential at point along the x-axis. Assume the potential is defined to be zero infinitely far away from the ring. (1 point)
(B) Determine the electric field vector at a point along the x-axis. (1 point)
(C) What is the electric field strength if $x \gg R_2$. Explain why this limit value makes sense. (1 point)
(D) What is the electric field strength if $x \ll R_1$. (1 point)
(E) A small negative charge $-q$ with mass m is placed on the x-axis, such that $x \ll R_1$. The negative charge, once released, will perform a harmonic oscillation. Determine the formula for the period of this harmonic oscillation. (1 point)

The next 20 questions are multiple choice question. Please use the multiple choice answer sheets to give your answer. A correct solution gives 1 point per question.

Question 1

A simple pendulum consists of a mass of 10 kg and a cord of 6.0 m has a period of T seconds. What would be the period if we increase the mass to 20 kg (keeping the cord length constant)? Consider that the cord does not stretch and that its mass is negligible.

(A) $T/2$
(B) $2T$
(C) $T/\sqrt{2}$
(D) T

Question 2

Consider a damped harmonic motion with a stiffness constant k and a mass m. What is the value of the damping constant b to have a critically damped system?

(A) $4mk$
(B) $2mk$
(C) $2\sqrt{mk}$
(D) $\sqrt{2}mk$

Question 3

The displacement of a traveling wave is described by the following equation

$$D(x,t) = 2.00\sin(5.20x - 12.57t + 1.20)$$

What is the period T?

(A) 0.080 s
(B) 0.19 s
(C) 0.013 s
(D) 0.50 s

Question 4

A wave crosses the boundary of two media. Its velocity decreases from 10 m/s to 6.0 m/s. If the wave strikes the boundary at an angle of 45°, what is the angle of refraction?

(A) 65°
(B) 45°
(C) 0.5°
(D) 25°

Question 5

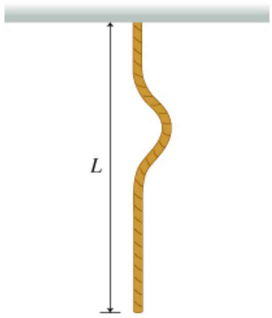
The sound level of an aircraft at a distance of 1 m is 135 dB, what is the sound level at 100 m? Ignore reflections from the ground and the atmospheric attenuation.

(A) 105 dB
(B) 115 dB
(C) 95 dB
(D) 89 dB

Question 6

A uniform rope of length L and negligible stiffness hangs from a solid fixture in the ceiling. The free lower end of the rope is struck sharply at time t=0. What is the time t it takes the resulting wave on the rope to travel to the ceiling, be reflected, and return to the lower end of the rope?

(A) $\sqrt{\frac{L}{g}}$
(B) $2\sqrt{\frac{L}{g}}$
(C) $4\sqrt{\frac{L}{g}}$
(D) $8\sqrt{\frac{L}{g}}$



Question 7

A steel rod is 100 m long at 20 °C. What is the increase in the length of the rod, if the temperature increases to 60 °C? The coefficient of linear expansion of steel is $12 \times 10^{-6}\ °C^{-1}$.

(A) 4.8 cm
(B) 2.4 cm
(C) 7.2 cm
(D) 4.4 cm

Question 8

A container is filled with a mixture of gases oxygen (O_2) and nitrogen (N_2) at the temperature of 25 °C. How would the average speed of the molecules compare?

(A) The oxygen molecules have a higher average speed because they are more massive.
(B) The nitrogen molecules have a higher average speed because they are less massive.
(C) The oxygen and nitrogen molecules have the same averaged speed because the temperature is the same.
(D) The oxygen and nitrogen molecules have the same averaged speed because they both are diatomic.

Question 9

The altitude of Mexico City is about 2216 meters above the sea level. While Singapore is at the sea level. How is the cooking time for people in Mexico City compared to in Singapore?

(A) The cooking time is longer in Mexico City than in Singapore.
(B) There is not enough information to answer this question.
(C) The cooking time is shorter in Mexico City than in Singapore.
(D) The cooking time is the same in both cities.

Question 10

In a closed room of size 5.0 m × 3.0 m × 3.0 m the temperature is 20 °C and the relative humidity is 60%. What is the mass of the water contained in the air of this room?

(A) 464 g
(B) 672 g
(C) 1120 g
(D) 765 g

Question 11

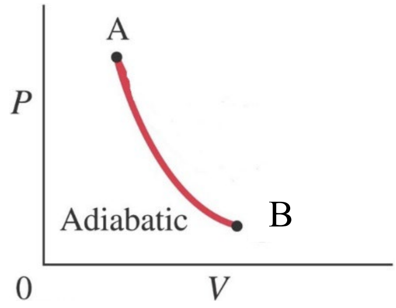
What is the net power that a person with a surface area of 1.5 m^2 radiates if his/her emissivity is 0.9, the skin temperature is 310 K, and the room temperature is 290 K?

(A) 132 W
(B) 144 W
(C) 166 W
(D) 147 W

Question 12

An ideal gas of *n* moles undergoes an adiabatic process from the point A to B as shown in the PV diagram. How does the entropy change in this process?

(A) The entropy decreases as the temperature decreases.
(B) The entropy increases as the internal energy decreases.
(C) The entropy change is zero as the temperature is constant.
(D) The entropy change is zero as the heat transfer is zero.



Question 13

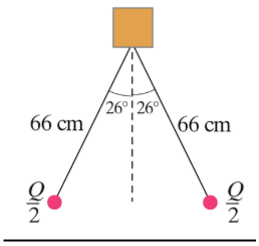
Regarding the Carnot cycle, which of the following statement is true?

(A) A Carnot cycle contains two adiabatic processes and two iso-volumetric processes.
(B) The Carnot cycle efficiency represents the typical efficiency value for a heat engine.
(C) To improve the Carnot cycle efficiency, increasing the high temperature from T_H to $T_H+\Delta T$ is more effective compared to reducing the low temperature T_L to $T_L-\Delta T$.
(D) To improve the Carnot cycle efficiency, reducing the low temperature T_L to $T_L-\Delta T$ is more effective compared to increasing the high temperature T_H to $T_H+\Delta T$.

Question 14

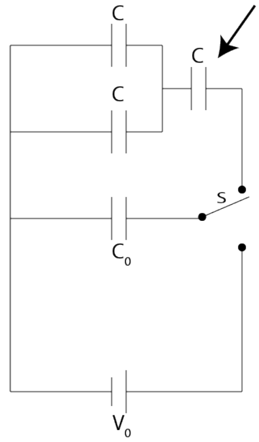
A large electroscope is made of "leaves" that are 66 cm long wires with tiny 26 g spheres at the ends. When charged, we assume that all the charge resides on the spheres. If the wires each make a 26° angle with the vertical as shown in the figure, what total charge must have been applied to the electroscope? Ignore the mass of the wires.

(A) 2.8 μC
(B) 3.1 μC
(C) 3.9 μC
(D) 4.3 μC



Question 15

The switch S in the figure is connected downward so that the capacitor C_0 becomes fully charged by the battery of voltage V_0. If the switch is then connected upward, what is the amount of charge q on the capacitor indicated by the arrow in the figure after steady state has been reached?



(A) $q = \frac{2CC_0}{2C+3C_0} V_0$

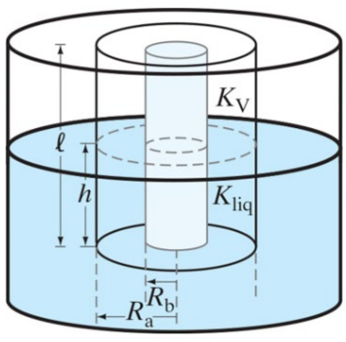
(B) $q = \frac{3CC_0}{2C+3C_0} V_0$

(C) $q = \frac{3CC_0}{3C+2C_0} V_0$

(D) $q = \frac{2CC_0}{3C+2C_0} V_0$

Question 16

The amount of kerosene in an airplane fuel tank is measured by a capacitive level sensor. This sensor is a vertically aligned cylindrical capacitor with outer and inner radii R_a and R_b, whose length l spans the height of the fuel tank. When kerosene fills the tank to a height h ($h \le l$) from the tank's bottom, the dielectric in the lower and upper regions between the cylindrical conductors is kerosene (K_{liq}) and its vapor (K_V), respectively, see the figure. By connecting a capacitance-measuring instrument to the level sensor the percentage of fuel in the tank can be determined. Assume the sensor dimensions are $l = 2.0$ m, $R_a = 5.0$ mm and $R_b = 4.5$ mm. For kerosene we have $K_{liq} = 2.0$ and for its vapor $K_V = 1.0$. The capacitance-measuring instrument measures a capacitance of 1400 pF. What is the percentage of fuel in the tank?



(A) 17%
(B) 33%
(C) 65%
(D) 73%

Question 17

A positive charge $+Q$ is positioned in the xy-plane at the point $(0,h)$. What is the change in potential energy to bring a charge q from $(0,L)$ to the origin, when $L > h > 0$?

(A) $\frac{qQ}{4\pi\epsilon_0}\left(\frac{1}{h}-\frac{1}{L}\right)$

(B) $\frac{qQ}{4\pi\epsilon_0}\,\frac{L}{h(h-L)}$

(C) $\frac{qQ}{4\pi\epsilon_0}\,\frac{2h-L}{h(h-L)}$

(D) That depends on the path taken from $(0,L)$ to $(0,0)$

Question 18

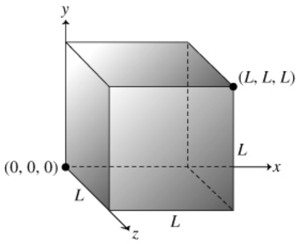
Two small non-conducting spheres have a total charge of 90 μC. When placed 1.16 m apart, the force each exerts on the other is 12.0 N and attractive. What is the charge on each sphere?

(A) 60.1 μC and 29.9 μC
(B) −16.8 μC and 73.2 μC
(C) −45.3 μC and 135 μC
(D) −16.8 μC and 107 μC

Question 19

A cube has one corner at the origin and the opposite corner at the point (L,L,L) . The sides of the cube are parallel to the coordinate planes. The potential field V in and around the cube is given by $V(x,y,z) = -Kxy$, where K is a constant. What is the net charge inside the cube?

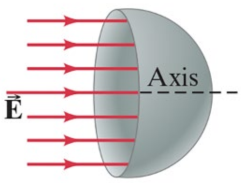
(A) 0
(B) $\epsilon_0 KL^2$
(C) $\frac{1}{2}\epsilon_0 KL^3$
(D) $\epsilon_0 KL^3$



Question 20

A uniform electric field $\vec{E}$ is parallel to the axis of a hollow hemisphere of radius r, see figure. What is the magnitude of the electric flux through the hemispherical surface?

(A) $\pi r^2|\vec{E}|$
(B) $\frac{4}{3}\pi r^2|\vec{E}|$
(C) $2\pi r^2|\vec{E}|$
(D) $4\pi r^2|\vec{E}|$



Fundamental constants

Quantity	Symbol	Value
Charge on electron	e	1.60×10^{-19} C
Rest mass electron	m_e	9.11×10^{-31} kg
Permittivity of free space	ε_0	8.85×10^{-12} $C^2/N \cdot m^2$
Universal gas constant	R	8.314 J/(mol K)
Stefan-Boltzmann constant	σ	5.67×10^{-8} W/(m^2 K^4)

TABLE 18–2 Saturated Vapor Pressure of Water

Temp-erature (°C)	Saturated Vapor Pressure torr (= mm-Hg)	Saturated Vapor Pressure Pa (= N/m^2)
−50	0.030	4.0
−10	1.95	2.60×10^2
0	4.58	6.11×10^2
5	6.54	8.72×10^2
10	9.21	1.23×10^3
15	12.8	1.71×10^3
20	17.5	2.33×10^3
25	23.8	3.17×10^3
30	31.8	4.24×10^3
40	55.3	7.37×10^3
50	92.5	1.23×10^4
60	149	1.99×10^4
70†	234	3.12×10^4
80	355	4.73×10^4
90	526	7.01×10^4
100‡	760	1.01×10^5
120	1489	1.99×10^5
150	3570	4.76×10^5

†Boiling point on summit of Mt. Everest.
‡Boiling point at sea level.

Properties of water

Specific heat of ice (-5 ºC)	2100 J/(kg ºC)
Specific heat of liquid (15 ºC)	4186 J/(kg ºC)
Specific heat of steam (110 ºC)	2010 J/(kg ºC)
Latent heat of fusion	333 kJ/kg
Latent heat of vaporization	2260 kJ/kg

Stefan-Boltzmann equation $\frac{Q}{t} = \epsilon\sigma A(T_1^4 - T_2^4)$