Description
This set of 1 statement of commitment to academic integrity and 15 questions is the final exam for PHYS 115 Fall 2021 at the University of Saskatchewan.

1/3 of the exam grade (10 marks) is based on the answers for the 10 multiple-choice questions submitted through WebAssign. All 10 multiple-choice questions are weighted equally.

2/3 of the exam grade (20 marks) is based on the answers (5 marks, submitted through WebAssign) and solutions (15 marks, submitted through Canvas) for the 5 word problems. All 5 word problems are weighted equally.

Instructions
Answers for **all** questions need to be submitted in WebAssign.

For each of questions 12, 13, 14, 15, and 16, in addition to submitting your answers in WebAssign, write the complete solution, **including a diagram**, using the problem-solving method discussed in class.

Your solutions must use the same symbols as are used on the formulae sheet.

Include a short sentence, a phrase, or a few words describing the principle(s) used in your solution.

Formulas not on the Formulae Sheet must be derived.

Keep extra decimal places throughout your calculations, and then round-off your final answer to three significant figures.

Submit your answer to each question in WebAssign.

When you have finished the entire exam, scan your written work for questions 12 through 16 and submit a single multi-page PDF file using the link in the Canvas site for your section.

Your WebAssign submission is due no later than 180 minutes (three hours) after the questions become available and your Canvas submission is due no later than 210 minutes (three-and-a-half) hours after the questions become available.

1. - UofS-P115-P117-Honour [4820285]
On my honour, I pledge that I will not give or receive aid during this assessment. I understand that I am expected to complete this assessment with no communication with other persons and no resource material other than the PHYS 115/117 Formulae sheet. I recognize that it is my responsibility to uphold academic integrity and I agree to follow the rules of this assessment and the guidelines laid forth in the policies of the University of Saskatchewan. Furthermore, I fully understand that disciplinary action may be taken against me if I am discovered to have communicated with another person or to have used an internet resource.

○ Yes, I understand and agree.

2. - P115-2021-FNL-1-A1 [5141051]

The difference in pressure, ΔP, between two points that are separated by a vertical distance of y in a fluid of density ρ is given by $\Delta P = \rho g y$. Water has a density of $\rho = 1.00 \times 10^3$ kg/m^3. Using the provided equation for ΔP, calculate the difference in pressure between two points that are separated by a vertical distance of 75.6 cm in a filled swimming pool.

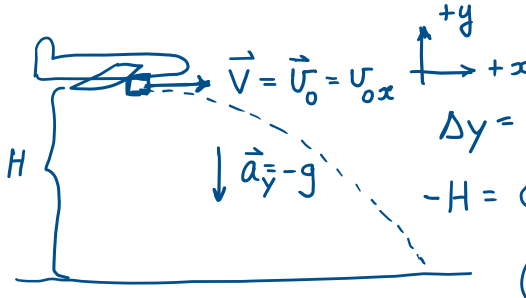
- 7.41×10^3 N
- 7.4×10^3 N/m^2
- 741 N
- [key] 7.41×10^3 N/m^2
- 7.41×10^5 N/m^2

$$\Delta P = \rho g y = (1.00\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(75.6\ \text{cm})\left(\frac{1\ \text{m}}{100\ \text{cm}}\right) = \boxed{7.41\times10^3\ \text{N/m}^2}$$

3. - P115-2021-FNL-1-A2 [5141052]

A package is released from a plane which is flying horizontally over flat horizontal ground. After release the package has an initial velocity which is the same as the plane. When the package is released, the plane is a height H above the ground and the speed of the plane is V. If we ignore air resistance, which statement is correct about the time interval between when the package is released and when it hits the ground?

- It depends on both H and V.
- It depends only on V and not on H.
- It does not depend on either H or V.
- [key] It depends only on H and not on V.



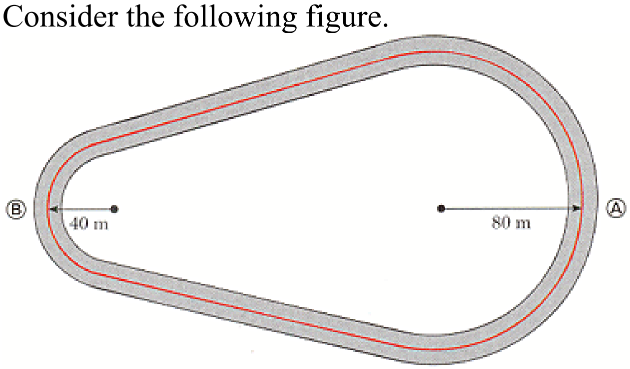
$$\Delta y = v_{0y} t + \tfrac{1}{2} a_y t^2$$

$$-H = 0 + (-g)t^2$$

$$\boxed{t = \sqrt{\frac{H}{g}}}$$

4. - P115-2021-FNL-1-A3 [5141072]

Consider the following figure.



$$a_c = \frac{v^2}{r}$$

$$\frac{a_{cA}}{a_{cB}} = \frac{v^2/r_A}{v^2/r_B} = \frac{r_B}{r_A} = \frac{40\ \text{m}}{80\ \text{m}} = \boxed{\frac{1}{2}}$$

A race track is constructed such that two curves of constant radius, 80 m at A and 40 m at B, are joined by two stretches of straight track as in the figure above.
While testing a new car, a driver travels at a constant speed of 50 m/s for one complete lap.
Which one of the following options is correct for the ratio of the centripetal acceleration of the car at A to the centripetal acceleration of the car at B?

- [key] $a_{cA}/a_{cB} = 1/2$
- $a_{cA}/a_{cB} = 1/4$
- $a_{cA}/a_{cB} = 2$
- $a_{cA}/a_{cB} = 4$
- The centripetal acceleration is zero at both points.

5. - P115-2021-FNL-1-A4 [5141045]
You wish to lift a box from the ground to the back of a truck. Which of the following methods of moving the box requires you to do the least amount of work on the box? Initially the box is at rest on the ground and finally it is at rest in the back of the truck.

- Slowly lifting the box vertically.
- All the described methods require you to do the same amount of work on the box.
- Rapidly lifting the box vertically.
- Rapidly sliding the box up a frictionless ramp.
- Slowly sliding the box up a frictionless ramp.

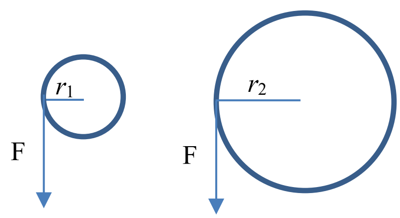
vertical distance from ground to truck

$\Delta KE = 0$, so $W_{tot} = 0$. $W_{tot} = W_{you} + W_{grav} = 0 \Rightarrow W_{you} = -W_{grav} = -(-mgh)$

$W_{you} = mgh$, independent of method

6. - P115-2021-FNL-1-A5 [5141077]
Using a screwdriver, you try to remove a screw from a piece of furniture, but can't get it to turn. To increase the chances of success, you should use a screwdriver that

- is longer.
- is shorter.
- has a narrower handle.
- has a wider handle.



$\tau_1 = r_1 F$ $\tau_2 = r_2 F$

Want to maximize the torque on the screw, so use a wider handle (increase r).

7. - P115-2021-FNL-1-A6 [5141046]
A star originates as a large body of slowly rotating gas. Because of gravitational attraction, this large body of gas slowly decreases in size. Which one of the following statements correctly describes what happens as the radius of the body of gas decreases? You can assume that no external forces are acting.

- Both the angular momentum and the angular velocity increase.
- The angular momentum remains constant and the angular velocity increases.
- Both the angular momentum and the angular velocity decrease.
- Both the moment of inertia and the angular velocity increase.
- The angular momentum increases and the angular velocity decreases.

$I_f \omega_f = I_i \omega_i$

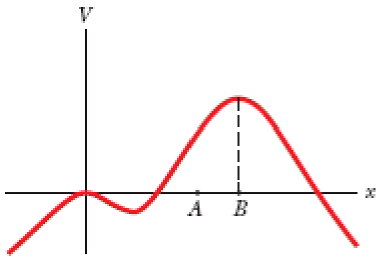
decrease in size $\Rightarrow I_f < I_i$

$\therefore \omega_f > \omega_i$

No external forces ⇒ No external torques ⇒ Ang. momentum is conserved!

8. - P115-2021-FNL-1-A7 [5141081]

The figure below is a graph of an electric potential as a function of position.



$\vec{E}$ points in the direction of decreasing potential, i.e. $\vec{E}_A$ points to the left. A positively-charged particle released at A will move to the left.

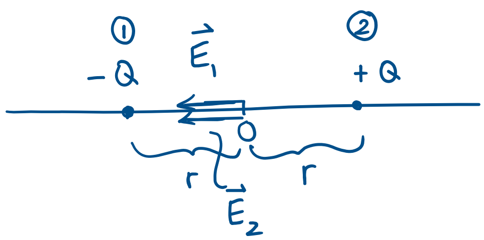
If a positively-charged particle is released from rest at point *A*, what will be its subsequent motion? The positively-charged particle will...

- move to the right.
- move to the left. (key)
- oscillate around point *B*.
- remain at point *A*.

9. - P115-2021-FNL-1-A8 [5141047]

Consider two point charges located on the *x*-axis. A charge $-Q$ is located at position $-r$ and a charge $+Q$ is located at position $+r$. The net electric field midway between the two charges at the origin of the *x*-axis is:

- zero.
- $2k_e|Q|/r^2$ in the $-x$ direction. (key)
- $k_e|Q|/r^2$ in the $+x$ direction.
- $2k_e|Q|/r^2$ in the $+x$ direction.
- $k_e|Q|/r^2$ in the $-x$ direction.

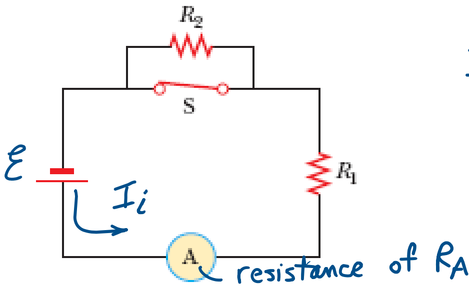


$$|E_1| = |E_2| = \frac{k_e|Q|}{r^2}$$

$$\therefore \vec{E}_{net} \text{ at origin} = \vec{E}_1 + \vec{E}_2 = \frac{2k_e|Q|}{r^2} \text{ in } -x\text{-dir'n}$$

10. - P115-2021-FNL-1-A9 [5141211]

In the figure below the current is measured with the ammeter at the bottom of the circuit.



$$I_i = \frac{\mathcal{E}}{R_A + R_1} \; ; \quad I_f \text{ when switch is opened} = \frac{\mathcal{E}}{R_A + R_1 + R_2}$$

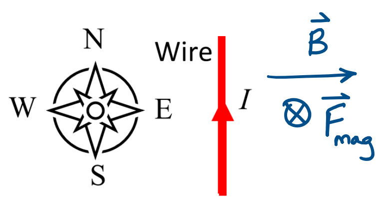
$$\therefore \; I_f < I_i$$

A circuit is comprised of two rectangular loops, one on top of the other. The bottom loop contains a battery on the left side with the positive terminal on the bottom, an ammeter on the bottom side, a resistor R_1 on the right side, and a closed switch on the top side. The top loop contains a resistor R_2 on the top side and a closed switch on the bottom side which is also the top side of the bottom loop. When the switch is opened, the reading on the ammeter...

- decreases (key)
- increases
- does not change

11. - P115-2021-FNL-1-A10 [5141212]

A horizontal wire carries a current to the North in a region of space where a magnetic field is horizontal and directed toward the East. In which direction is the magnetic force on this piece of wire?



$$\vec{F}_{mag} = \vec{I\ell} \times \vec{B}$$

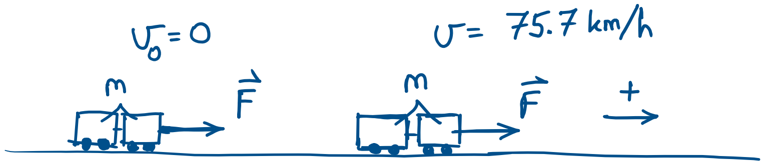
From RHR, $\vec{F}_{mag}$ is into page/screen, $\therefore$ Down

- East
- Up
- Down (key)
- West
- North

12. - P115-2021-FNL-1-B1 [5141053]

A locomotive exerts a constant force of 6.53×10^5 N on a train that has a mass of 1.01×10^7 kg. The train is on level rails. How much time does it take to increase the speed of the train from rest to 75.7 km/h? (Ignore air resistance and any resistance force from the rails on the wheels of the train. Enter your answer in minutes.) **To receive full marks, you must include a diagram showing the physical situation and your choice of coordinate system.**

5.42 min



$F = 6.53 \times 10^5$ N

$m = 1.01 \times 10^7$ kg

$v = \cancel{v_0}^{\,0} + at$ and $\Sigma \vec{F} = m\vec{a}$

$F = ma$

$a = \frac{F}{m}$

$$t = \frac{v}{a} = \frac{v}{F/m} = \frac{mv}{F} = \frac{(1.01 \times 10^7\ \text{kg})(75.7 \times 10^3\ \text{m/h})}{6.53 \times 10^5\ \text{kg} \cdot \text{m/s}^2} \cdot \frac{1\ \text{h}}{3600\ \text{s}} \cdot \frac{1\ \text{min}}{60\ \text{s}} = \boxed{5.42\ \text{min}}$$

Most, if not all, students will calculate a numerical value for accel'n.

$$a = \frac{F}{m} = \frac{6.53 \times 10^5\ \text{kg} \cdot \text{m/s}^2}{1.01 \times 10^7\ \text{kg}} = 6.465 \times 10^{-2}\ \text{m/s}^2$$

$$v = 75.7\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1000\ \text{m}}{\text{km}} = 21.03\ \text{m/s}$$

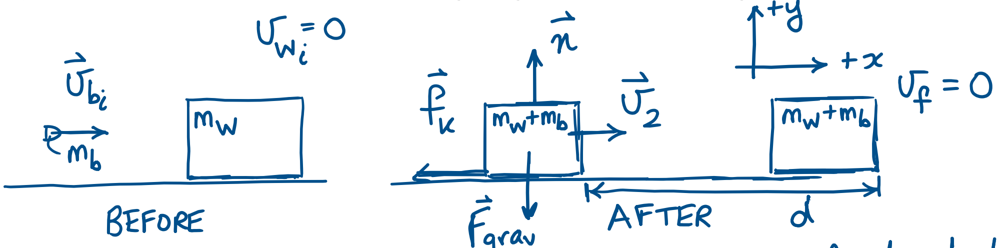
$$t = \frac{v}{a} = \frac{21.03\ \text{m/s}}{6.465 \times 10^{-2}\ \text{m/s}^2} \times \frac{1\ \text{min}}{60\ \text{s}} = \boxed{5.42\ \text{min}}$$

13. - P115-2021-FNL-1-B2 [5141075]

A block of wood, with mass 1.26 kg, rests stationary on horizontal ground. The coefficient of kinetic friction between the block and the ground is 0.905. A bullet, with mass 0.250 kg, moving horizontally hits and sticks into the block of wood. We find that the speed of the block of wood, with the bullet embedded in it, just after the collision is 13.5 m/s. **To receive full marks, you must include a diagram showing the physical situation and your choice of coordinate system.**

(a) Calculate the speed of the bullet before hitting the block of wood. 81.5 m/s

(b) Calculate how far the block slides along the ground before coming to rest. 10.3 m



(a) Momentum is conserved during the collision of the bullet and block.

$$\vec{P}_{tot_i} = \vec{P}_{tot_f} \Rightarrow m_b v_{b_i} = (m_w + m_b) v_2 \Rightarrow v_{b_i} = \left(\frac{m_w + m_b}{m_b}\right) v_2$$

$$v_{b_i} = \left(\frac{(1.26\text{ kg} + 0.250\text{ kg})}{0.250\text{ kg}}\right) 13.5\text{ m/s} = 81.54\text{ m/s} = \boxed{81.5\text{ m/s}}$$

(b) After the collision: $W_{tot} = \Delta KE \Rightarrow W_{fr} = 0 - KE_i \Rightarrow (f_k \cos 180°) d = -\frac{1}{2}(m_w + m_b) v_2^2$

$$\sum F_y = 0 \Rightarrow +n - F_{grav} = 0 \Rightarrow n = (m_w + m_b) g \;;\; f_k = \mu_k (m_w + m_b) g$$

$$\therefore -f_k d = -\frac{1}{2}(m_w + m_b) v_2^2 \Rightarrow \cancel{-}\mu_k \cancel{(m_w + m_b)} g d = \cancel{-}\frac{1}{2}\cancel{(m_w + m_b)} v_2^2$$

$$d = \frac{v_2^2}{2\mu_k g} = \frac{(13.5\text{ m/s})^2}{2(0.905)(9.80\text{ m/s}^2)} = \boxed{10.3\text{ m}}$$

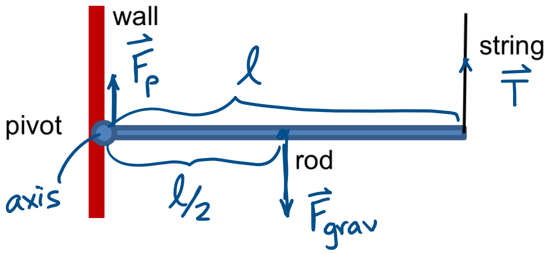
Alternate Solution: $\sum F_x = (m_w + m_b) a \Rightarrow -f_k = (m_w + m_b) a$

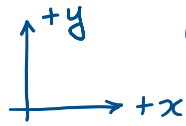
$$-\mu_k (m_w + m_b) g = (m_w + m_b) a \Rightarrow a = -\mu_k g = -(0.905)(9.80\text{ m/s}^2) = -8.869\text{ m/s}^2$$

$$v_f^2 = v_2^2 + 2a\Delta x \Rightarrow \Delta x = \frac{v_f^2 - v_2^2}{2a} = \frac{0 - (13.5\text{ m/s})^2}{2(-8.869\text{ m/s}^2)} = \boxed{10.3\text{ m}}$$

14. - P115-2021-FNL-1-B3 [5141080]

A uniform rod has a mass of 2.12 kg and has a length of 1.13 m. It is hinged to a wall by a pivot at one end and is held in a horizontal position by a light vertical string attached to the other end as shown. **To receive full marks, you must include a diagram showing the physical situation and your choice of coordinate system.**





(a) For the rod:

$$\Sigma\vec{\tau} = 0 \text{ and } \Sigma\vec{F}_y = 0$$

$$+\tau_T - \tau_{F_{grav}} = 0$$

$$T\ell = mg\frac{\ell}{2} \Rightarrow T = \frac{mg}{2}$$

$$T = \frac{(2.12\,kg)(9.80\,m/s^2)}{2} = 10.388\,N = \boxed{10.4\,N}$$

(a) Calculate the magnitude of the tension in the string. 10.4 N

(b) The string is now cut. Calculate the magnitude of the angular acceleration (in rad/s^2) of the rod about the pivot point just after the string is cut. Ignore the mass of the string. ~~26~~ 13 rad/s^2

(b) At the instant that the string is cut, the only torque acting on the rod is due to $\vec{F}_{grav}$.

$$\Sigma\tau = I\alpha \Rightarrow -mg\frac{\ell}{2} = \frac{1}{3}m\ell^2 \cdot \alpha$$

thin rod rotating around axis through one end.

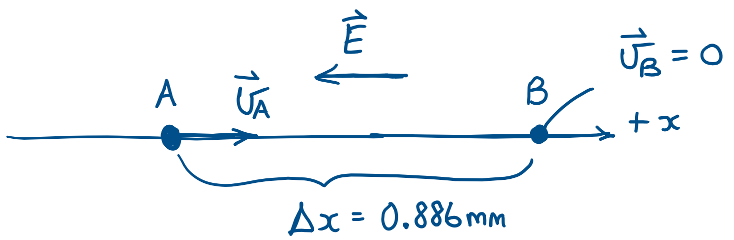
$$\alpha = -\frac{3g}{2\ell} = -\frac{3(9.80\,m/s^2)}{(2)(1.13\,m)} = -13.0\,rad/s^2 \text{ ; magnitude: } \boxed{13.0\,rad/s^2}$$

15. - P115-2021-FNL-1-B4 [5141083]

An ionized nitrogen molecule (N_2^+) at point A has charge $+e$ and moves at 1.80×10^3 m/s in the positive x-direction. A constant electric force in the negative x-direction slows the molecule to a stop at point B, a distance of 0.886 mm past A on the x-axis. The mass of a nitrogen molecule is 4.65×10^{-26} kg and the fundamental charge is $e = 1.602 \times 10^{-19}$ C. **To receive full marks, you must include a diagram showing the physical situation and the coordinate system.**

(a) Calculate the magnitude of the electric field (in V/m) 531 V/m

(b) Calculate the potential difference $V_B - V_A$ between points A and B (in V) 0.47 V



(a) Method 1: $\sum \vec{F} = m\vec{a} \Rightarrow -qE = ma \Rightarrow a = -\frac{qE}{m}$; $v_B^2 = v_A^2 + 2a\Delta x$

$$\therefore 0 = v_A^2 + 2\left(-\frac{qE}{m}\right)\Delta x \Rightarrow \frac{2qE\Delta x}{m} = v_A^2 \Rightarrow E = \frac{m v_A^2}{2q\Delta x}$$

$$E = \frac{(4.65\times10^{-26}\,\text{kg})(1.80\times10^3\,\text{m/s})^2}{2(1.602\times10^{-19}\,\text{C})(0.886\,\text{mm})} \times \frac{1000\,\text{mm}}{\text{m}} = 530.7\,\text{N/C} = \boxed{531\,\text{N/C}}$$

Method 2: $W_{net} = \Delta KE \Rightarrow F_{el}(\cos 180°)(\Delta x) = 0 - \frac{1}{2}m v_A^2$

$$-qE\Delta x = -\frac{1}{2}m v_A^2 \Rightarrow E = \frac{m v_A^2}{2q\Delta x}$$ (same as above in Method 1)

(b) Method 1: F_{el} is conservative, so $KE_B + PE_B = KE_A + PE_A$

$$0 + qV_B = \frac{1}{2}m v_A^2 + qV_A \Rightarrow V_B - V_A = \frac{m v_A^2}{2q} = \frac{(4.65\times10^{-26}\,\text{kg})(1.80\times10^3\,\text{m/s})^2}{2(1.602\times10^{-19}\,\text{C})}$$

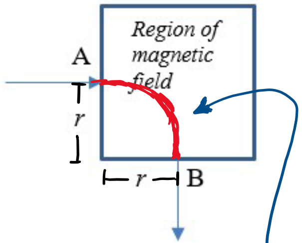
$$V_B - V_A = \boxed{0.470\,\text{V}}$$

Method 2: $\Delta V = -E\Delta x = -(-530.7\,\text{N/C})(0.886\times10^{-3}\,\text{m}) = \boxed{0.470\,\text{V}}$

(in this equation, E and Δx are "signed" quantities)

16. - P115-2021-FNL-1-B5 [5141213]

Beams of electrons can be steered using magnets. It is desired to change the trajectory of a beam of electrons by passing the beam through a magnetic field as shown in the diagram, where $r = 4.52$ cm. The electrons enter the magnetic field at A and leave the magnetic field at B.



(a) Draw a diagram showing the path followed by the electrons while they are in the magnetic field, i.e. the path from A to B.

(b) The electrons have kinetic energies of 3.93 keV. Calculate the required magnetic field (magnitude and direction). You may assume that the magnetic force is the only force acting on the electrons. The mass of an electron is 9.11×10^{-31} kg. Which one of the following is the required direction of the magnetic field?

- to the left
- toward the bottom of the page
- into the page ← from RHR.
- to the right
- out of the page
- toward the top of the page

Required magnitude of magnetic field: 0.00468 T

(b) Magnetic force produces the required centripetal acceleration.

$$\Sigma\vec{F} = m\vec{a}_c \Rightarrow F_{mag} = ma_c \Rightarrow qvB = \frac{mv^2}{r} \Rightarrow qB = \frac{mv}{r} \Rightarrow B = \frac{mv}{qr}$$

$$KE = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(3930\,\text{eV})(1.602\times10^{-19}\,\text{C/e})}{9.11\times10^{-31}\,\text{kg}}} = 3.718\times10^{7}\,\text{m/s}$$

$$B = \frac{(9.11\times10^{-31}\,\text{kg})(3.718\times10^{7}\,\text{m/s})}{(1.602\times10^{-19}\,\text{C})(0.0452\,\text{m})} = \boxed{4.68\times10^{-3}\,\text{T}}$$