General Physics I: Midterm Exam (113–1)

100 minutes, full mark = 50

Use of your notebooks/memos/books:	Strictly forbidden.
Use of your mobile etc. & Internet:	Strictly forbidden.
Discussion with other attending students:	Strictly forbidden.

Administrative Remarks

- Write your name and student ID on the answer sheet. Put your student ID on the desk.
- Allowed on your desk: student ID card (required), pens/pencils, correction tools (eraser etc.), rulers, and drinks. **Other items must be stored in your bags.**
- You cannot wear watches nor electronic devices. **You cannot have them even in your pockets**.
- **After 9:10, the following actions are considered cheating. You may immediately lose your credit.**
  - If non-allowed items (pen cases, foods, poaches, etc.) are found on desks.
  - If you have textbooks, mobile phones, tablets, or PC, if they are not stored in your bags, or if you use them. They must be in your bags even after you submit your answer sheets.
- Breaks are not allowed in principle. After 10:00, you may leave after submission. In case of health problems or other issues, call the TA or lecturer.
- *Any form of academic dishonesty, including chats, additions/corrections after the period, and using your phones, will be treated by NSYSU "Academic Regulations."*

Scientific Remarks

- Show your calculations or thought process for **partial mark**!
- Use English, where mistakes are tolerated. Meanwhile, scientific mistakes are not tolerated.
  - Provide appropriate **units** properly. Handle **significant digits** properly.
  - Clearly distinguish **vectors** (by writing $\vec{E}$, $\vec{x}$ or $\mathbb{E}$, $\mathbb{x}$) from scalars (E, x).
- If you find any errors or issues in the questions, explain them on your answer sheet, make necessary adjustments on the question, and answer accordingly.
- You may use the following symbols and values without definition/declaration.

standard acceleration of gravity	g	$= 9.8\,\mathrm{m/s^2}$
Newtonian constant of gravitation	G	$= 6.7\times10^{-11}\,\mathrm{N\cdot m^2/kg^2}$
elementary charge	e (or $\lvert e\rvert$)	$= 1.6\times10^{-19}\,\mathrm{C}$
permittivity of free space	ϵ_0	$= 8.9\times10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$
permeability of free space	$\mu_0 = \left(\epsilon_0 c^2\right)^{-1}$	$= \pi\times 4.0\times10^{-7}\,\mathrm{N/A^2}$
Coulomb constant	$k_e = \left(4\pi\epsilon_0\right)^{-1}$	$= 9.0\times10^{9}\,\mathrm{N\cdot m^2/C^2}$
speed of light in vacuum	c	$= 3.0\times10^{8}\,\mathrm{m/s}$
Avogadro's number	N_A	$= 6.0\times10^{23}/\mathrm{mol}$
masses of protons and electrons	m_p, m_e	$= 1.7\times10^{-27}\,\mathrm{kg}, 9.1\times10^{-31}\,\mathrm{kg}$

Unit vectors in the direction of the axes $(\vec{e_x}, \vec{e_y}, \vec{e_z})$ or $(\hat{e}_x, \hat{e}_y, \hat{e}_z)$ or $(\hat{\imath}, \hat{\jmath}, \hat{k})$

$\vec{E}(\vec{x})$	electric field at $\vec{x}$	$\vec{B}(\vec{x})$	magnetic field (magnetic flux density) at $\vec{x}$
$V(\vec{x})$	electrostatic potential at $\vec{x}$	$\vec{F}_{XY}$	force exerted by X on Y

$\sqrt{2}\approx 1.414$ $\sqrt{3}\approx 1.732$ $\sqrt{5}\approx 2.236$ $\sqrt{7}\approx 2.646$ $\pi\approx 3.142$ $\mathrm{e}\approx 2.718$

Answer **[Part A]**, **[Part B]**, and **[Part C]**. In addition, if you are a first-year student, answer either **[Part D]** or **[Part E]**. If not, answer **[Part E]**.

[Part A] Mini Test Review (12 points)

- A particle moves in the xy-plane, starting from the origin at $t = 0$ with an initial velocity having an x component of $+3.0\,\mathrm{m/s}$ and a y-component of $+1.0\,\mathrm{m/s}$. It experiences an acceleration of $+0.50\,\mathrm{m/s^2}$ in the y-direction.

  (1) Calculate the speed at $t = 4.0\,\mathrm{s}$.

  (2) Give the position vector at $t = 4.0\,\mathrm{s}$.

  (3) Find the average velocity between $t = 0$ and $t = 4.0\,\mathrm{s}$.

- Calculate the following differentials.

  (4) $\dfrac{\mathrm{d}}{\mathrm{d}x}\dfrac{1}{1+x}$ **(5)** $\dfrac{\mathrm{d}}{\mathrm{d}x}\dfrac{1}{x\sqrt{x}}$ **(6)** $\dfrac{\mathrm{d}}{\mathrm{d}x}3\cos 2x$

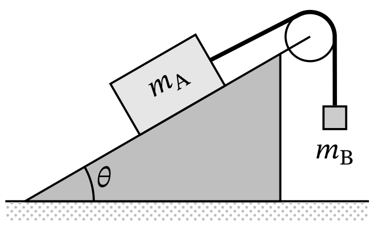
[Part B] Fundamental Problems (14 points)

(1) The position of a particle varies in time t according to $\vec{r} = ct\vec{e_x} - at^2\vec{e_y}$, where a and c are constants. Find a) the velocity, b) speed, and c) acceleration of the particle as functions of t.

(2) Consider a satellite in a circular orbit around the Earth. Assume its mass is $1.0 \times 10^3\,\mathrm{kg}$, the circumference of the orbit is $1.0 \times 10^5\,\mathrm{km}$, and its period is $2.0 \times 10^4\,\mathrm{s}$. Calculate a) its speed, b) angular speed, and c) the magnitude of the net force causing the centripetal acceleration.

(3) A block with mass M is sliding down a frictionless plane having an inclination θ.
a) Identify all forces exerted **by** the block. (No need to describe the direction and magnitude.)
b) Find the acceleration of the block.

[Part C] Forces and Motion (14 points)



As in the right figure, a wedge with an angle θ is fixed on the ground, Block A is on its slope, and Block B is connected to Block A by a wire through a pulley.

Block A has a mass m_A and can move only on the slope. Block B has a mass m_B and can move only vertically. Between Block A and the slope, the coefficient of kinetic friction is μ_k and the static-friction coefficient is μ_s. The wire has a negligible mass and does not stretch. Assume its tension is positive throughout this problem. Friction on the pulley is negligible.

When you first see it, Block A is moving down the slope.

(1) Identify all the forces exerted **on** Block A. For each force, describe its direction.

(2) Calculate the acceleration of Block A (at this moment).

(3) Calculate the tension of the wire (at this moment).

Soon after that, Block A slows down and stops on the slope. Then, you replace Block B by another block with mass M, but Block A does not start moving and remains stationary.

(4) Describe what is known about the value of M.

[The exam questions continue on the next page.]

If you are a first-year student, answer **[Part D]** or **[Part E]**. If not, answer **[Part E]**.
Do not solve both. Please specify clearly which part you answer.

[Part D] Learning at University (12 points)

Almost all first-year university students encounter learning challenges due to the differences in the learning environment compared to high school. How about you?

(1) Identify three major differences between learning in university and learning in high school that may present challenges for students *in your department*.

(2) How can students overcome those differences? Suggest three specific strategy.

Now, imagine another parallel universe, where we have a "perfect translator" and we can speak any language. There, Sho is doing this lecture in your first language (i.e., 國語 for most of you). Then...

(3) Would your understanding of physics (and the exam result) be better/worse/unchanged? Choose your answer and give a bried explanation (one or two sentences).

[Part E] Proof-based Problems (12 points)

(1) Give the definition of $\frac{\mathrm{d}f(x)}{\mathrm{d}x}$ for a function $f(x)$ and prove $\frac{\mathrm{d}}{\mathrm{d}x}x^3 = 3x^2$ based on the definition.

(2) Consider a uniform circular motion with radius r and angular speed ω. Its centripetal acceleration a_c is given by $a_c = r\omega^2$. Derive this formula.

[The exam questions continue on the next page.]

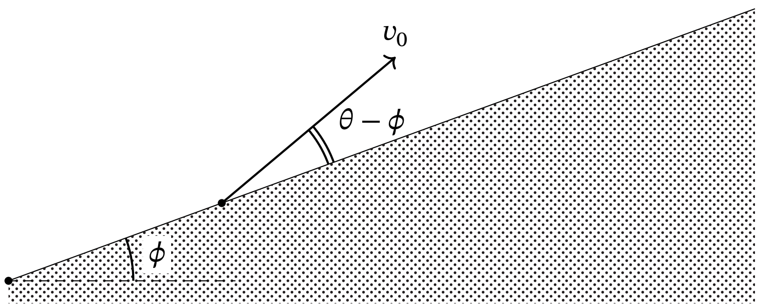
[Part F] Extra Problem (unlimited points)

> This is an extra challenging problem. You may try writing something for a partial mark, because no penalty is given for incorrect answer as long as you are a student.

You are on a slope and going to fire a projectile with a fixed initial speed v_0. As in the figure below, the slope has an incline angle ϕ (in the firing direction) and you can vary the launch angle θ, where ϕ and θ are measured from the horizontal and thus $\phi < \theta \leq \pi/2$.

Assume the projectile flies for a duration Δt and lands at a distance L from the launch point. Answer the following questions, assuming that the air-resistance is negligible and the slope is sufficiently long. You can ignore the fact that the Earth is round and use the standard gravitational acceleration g throughout your answer, because v_0 is much smaller than 1 km/s.

- First, assume the sky is clear and has no wind. The projectile in flight will experience only the gravitational force.
  - **(1)** Find the angle θ that maximizes Δt.
  - **(2)** Find the angle θ that maximizes L.
- What if it is a windy day? If the wind velocity were $\vec{v}_{\text{wind}}$, then, according to the air-resistance model, it should give a force $\vec{F}_{\text{wind}} \approx b(\vec{v}_{\text{wind}} - \vec{v}_{\text{projectile}})$ and ..... oh, this is a very complicated differential equation.
  - **(3)** Here, as a very crude approximation, let us model it as a constant acceleration. Namely, we assume that the projectile experiences a constant acceleration a in the horizontal direction as well as the vertical gravitational acceleration.
    Based on this model, discuss anything, such as the angle that maximizes Δt, maximizes L, or minimizes L.



[This is the end of the exam questions.]