上 海 交 通 大 学 试 卷

（ 2019 - 2020 Academic Year/ Summer Semester ）

Midterm Exam

VP160 Honors Physics I

23 June 2020

16:00-17:40

You are to abide by the University of Michigan-Shanghai Jiao Tong University Joint Institute (UM-SJTU JI) Honor Code. Please attach the Honor Code pledge to your solutions.

- **Please carefully read instructions in the exam paper.**
- **Part I of the exam is to be completed on Canvas within a given time limit and submitted before the specified time.**
- **Solutions to exam questions in Parts II and III must be submitted as a pdf file to Canvas assignment 'Midterm Exam' no later than 17:50 (23 June 2020).**
- **In case you have a question, please raise your hand or send a zoom message to the instructor/TA.**

PART I: Quiz *(10 questions, total 20 points)*

Please visit Canvas/Quizzes to complete this part. There is a time limit of 20 minutes for this part and it must be completed before 4.30 p.m.

PART II: Computational/Conceptual Questions *(6 questions, total 21 points)*

Please remember to explain your answers!

Question 1. (*2 points*) Let $\overline{u} = 3\hat{n}_x - 2\hat{n}_y + \hat{n}_z$ and $\overline{w} = \hat{n}_x - 4\hat{n}_y + 2\hat{n}_z$.

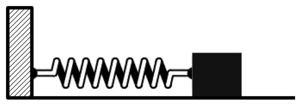
What is the orthogonal projection of the vector $(\overline{u} - 2\overline{w})$ onto the vector $\overline{u} \times \overline{w}$?

Question 2. (*5 points*) A particle of mass m moves along the x axis so that in order to travel from the origin to the point x, it needs time $t = Ax^2 + Bx + C$, where A, B, C are positive constants. The particle is subject to a drag force bv^n (where $b > 0$ is constant), which is the only force acting on the particle.

What is the value of n?

Question 3. (*3 points*) Find work done by the force $\overline{F} = (2xy + 1)\hat{n}_x + x^2 z\hat{n}_z$ [N] on a particle moved from the point $(0, 0, 0)$ to $(1, 1, 1)$ along the curve traced by the tip of the vector $\overline{r}(t) = t\hat{n}_x + t^2\hat{n}_y + t\hat{n}_z$ [m].

Question 4. (*4 points*) One end of a massive spring with mass M and equilibrium length L, satisfying Hooke's law with a spring constant k, is fixed to a wall. There is a block with mass m attached to the other end. The spring is stretched from its equilibrium length by A.



What is the period of the resulting oscillations?

Assume that the speed of points along the length of the spring varies linearly with distance from the fixed end. Assume also that the mass of the spring is distributed uniformly along the length of the spring.

Question 5. (*4 points*) Recall that the steady-state solution for a damped harmonic oscillator with a sinusoidal driving force of angular frequency $\omega_{\rm dr}$ is of the form $x_{\rm s}(t) = A\cos(\omega_{\rm dr}t + \phi)$, where A is the amplitude and ϕ is the phase lag.

Recall that A and ϕ are determined by parameters of the system, such as the mass of the oscillating particle, drag coefficient, natural angular frequency, amplitude and frequency of the driving force etc. The initial position and the initial velocity of the oscillating particle do not enter the formulas for A and ϕ.

It seems to contradict the statement that the general solution of any Newton's equation of motion should have two constants (free parameters) whose values are determined by applying initial conditions. Explain whether there is a contradiction here or not.

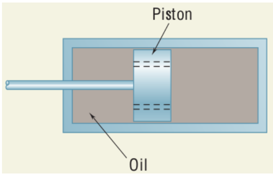
Question 6. (*3 points*) Is it possible that, in a non-inertial frame of reference, the Coriolis force and the centrifugal force — acting at the same instant of time and on the same particle — are both equal to zero, but the Euler force (acting at the same instant of time and on the same particle) is not zero?

Continued on the next page!

PART III: Problems *(6 problems, total 59 points)*

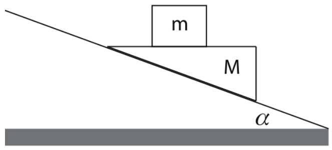
Solve the following problems. Show all your work.

Problem 1. *(9 points)* A brake mechanism used to reduce recoil in a launcher consists of a piston with mass m attached to the barrel and moving in a fixed cylinder filled with oil. As the barrel recoils with some initial velocity, the piston moves and oil is pressed through small holes in the piston, exerting a drag force on the the piston and the barrel and causing them to decelerate.



Suppose that the magnitude of that drag force is bv^2, where v is the speed of the piston and b is the drag coefficient. What is the distance the piston moves before its speed decreases to a half of the initial value?

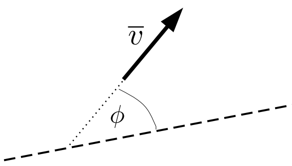
Problem 2. *(12 points)* A wedge with mass M is placed on a frictionless fixed plane inclined at an angle α. The upper surface of the wedge is horizontal. A block with mass m is placed on top of the wedge. The system is released from rest. Assuming that there is no friction between M and m, find the acceleration of the block m with respect to the wedge M just after the system is released from rest. The acceleration due to gravity g is known.



Problem 3. *(12 points)* An object with mass M, moving along a straight line on a flat horizontal ground, is propelled by an engine delivering constant power. The coefficient of kinetic friction between the object and the ground is constant. After a period of time t, the object moves forward a distance s, and its speed increases from the initial speed v_0 to the maximum speed $v_{\max}$.

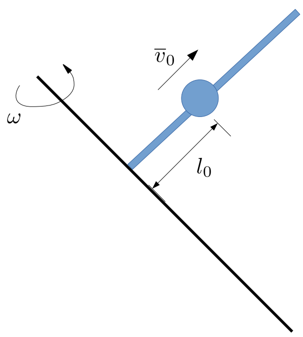
Find the power P delivered by the engine, and the coefficient of kinetic friction μ. The acceleration due to gravity is equal to g.

Problem 4. *(12 points)* A particle moves in a plane so that the angle between the particle's instantaneous velocity $\overline{v}$ and its instantaneous acceleration $\overline{a}$ is constant and equal to α. Let ϕ be the angle that the vector $\overline{v}$ forms with a fixed direction on that plane (see the figure). Initially, the speed of the particle $|\overline{v}(0)| = v_0$ and $\phi(0) = \phi_0$.



Find the instantaneous speed of the particle as a function of the angle ϕ.

Problem 5. *(14 points)* A bead slides on a rough rod that is firmly attached, at the right angle, to an axle inclined at the angle 45° to the horizontal. The axle spins with constant angular velocity $\overline{\omega}$, as shown in the figure below. Initially, the bead is a distance l_0 from the axle and moves with velocity $\overline{v}_0$ with respect to the rod (see the figure).



The instantaneous speed of the bead with respect to the rod turns out to increase linearly with the distance l from the axle as $v = v_0 l / l_0$.

(a) What is the coefficient of kinetic friction between the rod and the bead?

(b) Under what condition (express it in terms of ω, v_0 and l_0) is the described situation is possible?

There is no gravitational force in this problem.

Please clearly indicate the frame of reference you are solving the problem in.

[End of the exam paper]