AAPT UNITED STATES PHYSICS TEAM
AIP 2002

Preliminary Exam
Open Response Questions

4 Questions, 60 minutes

INSTRUCTIONS
DO NOT OPEN THIS TEST UNTIL YOU ARE TOLD TO BEGIN

- Show all your work. Partial credit will be given.
- Start each question on a new sheet of paper. Be sure to put your name in the upper right-hand corner of each page, along with the question number and the page number/total pages for this problem. For example,

  Doe, Jamie
  Q1 – 1/3
- A hand-held calculator may be used. Its memory must be cleared of data and programs. You may use only the basic functions found on a simple scientific calculator. Calculators may not be shared. You may not use any tables, books, or collections of formulas.
- Each of the four questions is worth 25 points. The questions are not necessarily of the same difficulty.

Possibly Useful Information

Gravitational field at the Earth's surface $g = 9.8$ N/kg
Newton's gravitational constant $G = 6.67 \times 10^{-11}$ N·m²/kg²
Binomial expansion $(1 + x)^n \approx 1 + nx$ for $|x| << 1$

Moment of Inertia about Center of Mass – Uniform Object
(will not be provided on the second screening exam)

Disk	$\frac{1}{2} MR^2$
Sphere	$\frac{2}{5} MR^2$
Rod	$\frac{1}{12} ML^2$

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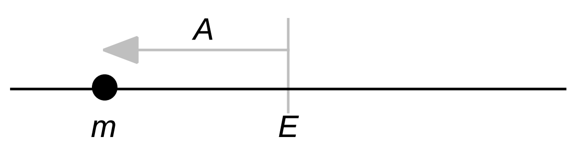
1. A rocket of mass m is launched straight up, reaches a maximum height H above the ground, and begins its vertical descent. The rocket is in free fall until it falls to a height h. At that point, the rocket's engines are fired and provide a continuous upward thrust F. You may neglect the following: air resistance; any horizontal motion of the rocket; and any change in the mass of the rocket. Express your answers in terms of only the variables given (H, F, m) and, if necessary, the gravitational field at the Earth's surface g and the radius of the Earth R_E.

(10) a. H is small enough that the force of gravity is constant during the flight of the rocket. At what height h above the surface of the Earth should the engines be fired so that the rocket lands safely with zero velocity?

(5) b. For what values of F is a zero velocity landing impossible?

(10) c. H is large enough that the force of gravity is not constant during the flight of the rocket. At what height h above the surface of the Earth should the engines be fired so that the rocket lands safely with zero velocity?

2. A particle of mass m is constrained to move in one dimension. A force $\boldsymbol{F}$ acts on the particle. $\boldsymbol{F}$ always points toward the position labeled E. For example, when the particle is to the left of E, $\boldsymbol{F}$ points to the right. The magnitude of $\boldsymbol{F}$ is a constant F except at point E where it is zero.



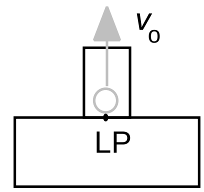
(10) a. The system is horizontal. $\boldsymbol{F}$ is the net force acting on the particle. The particle is displaced a distance A from the equilibrium position E and released from rest. What is the period of the motion?

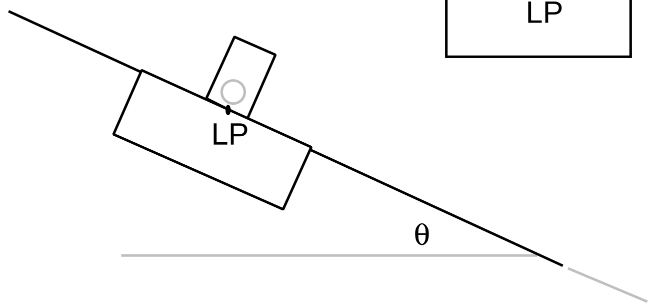
(15) b. The system is vertical. Both the force $\boldsymbol{F}$ described above and gravity act on the system. The particle is displaced a distance A above the position E and released from rest. $F > mg$. What is the period of the motion?

3. An air track glider is fitted with a launcher that fires a projectile with velocity v_o perpendicular to the glider. The launch point LP is marked on the glider, as shown in the diagrams. The glider is placed on a very long air track, which is inclined at an angle θ to the horizontal. With the air turned on, the system can be considered frictionless. With the air turned off, the coefficient of friction between the track and glider is μ. The projectile is launched at the instant the glider has velocity v down the track and lands a distance x down the track. While the projectile is in the air, the point LP moves a distance x_{LP}. What is $\Delta x = x - x_{LP}$, if:

(20) a. the air is off?

(5) b. the air is on?





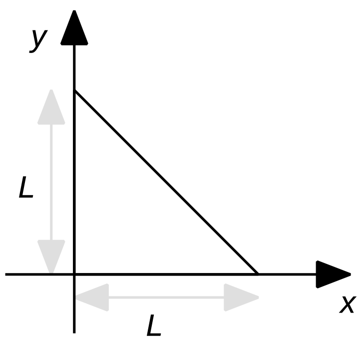


Fig. 4-1

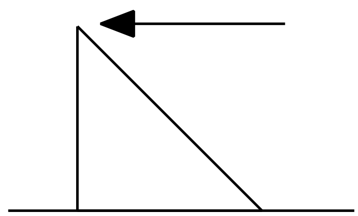


Fig. 4-2

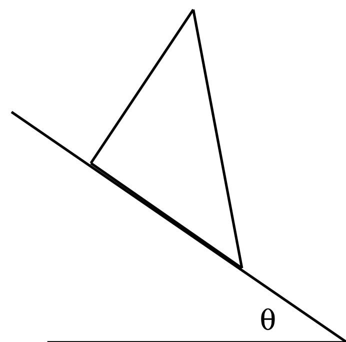


Fig. 4-3

(25) 4. A wooden 45° right triangle has uniform mass M and two equal sides of length L. The coordinates of the triangle's center of gravity, measured with respect to the axes shown in Fig. 4-1 above, are

$$x_{cg} = L / 3 \qquad\qquad y_{cg} = L / 3.$$

The triangle is placed on a rough horizontal surface and a horizontal force is applied at the top of the triangle, as shown in Fig. 4-2. The force is gradually increased until the triangle just starts to tip over without sliding. The force is then removed and the surface is inclined as shown in Fig 4-3. The triangle is placed on the inclined plane. For what range of angle θ, measured with respect to the horizontal, can you be certain that the triangle will not slide?

The 2002 Preliminary Examination open response questions were written by the coaches of the United States Physics Team. The coaches are: Academic Director, Mary Mogge – Professor of Physics at California State Polytechnic University, Pomona, CA; Senior Coach, Leaf Turner – Physicist in the Theoretical Division of Los Alamos National Laboratory, Los Alamos, NM; Warren Turner – Physics Teacher at Massachusetts Academy of Math and Science, Worcester, MA; Robert Shurtz – Physics Teacher at the Hawken School, Gates Mills, OH. Questions 1 and 3 were suggested by Warren Turner, Question 2 by Mary Mogge, and Question 4 by Leaf Turner.