2000 Advanced Placement Program®
Free-Response Questions

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The College Board

PHYSICS B

SECTION II

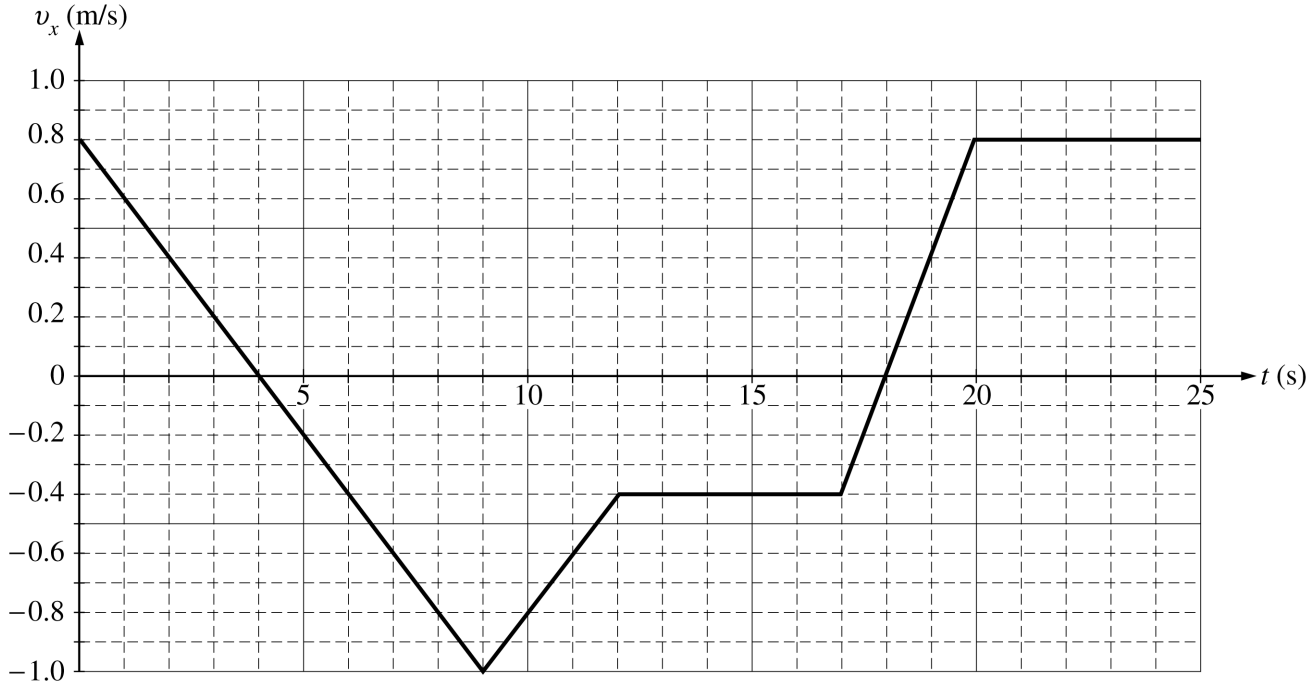
Time—90 minutes

7 **Questions**

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested time is about 15 minutes for answering each of questions 1-4, and about 10 minutes for answering each of questions 5-7. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.

1. (15 points)

A 0.50 kg cart moves on a straight horizontal track. The graph of velocity v_x versus time t for the cart is given below.



(a) Indicate every time t for which the cart is at rest.

(b) Indicate every time interval for which the speed (magnitude of velocity) of the cart is increasing.

(c) Determine the horizontal position x of the cart at $t = 9.0$ s if the cart is located at $x = 2.0$ m at $t = 0$.

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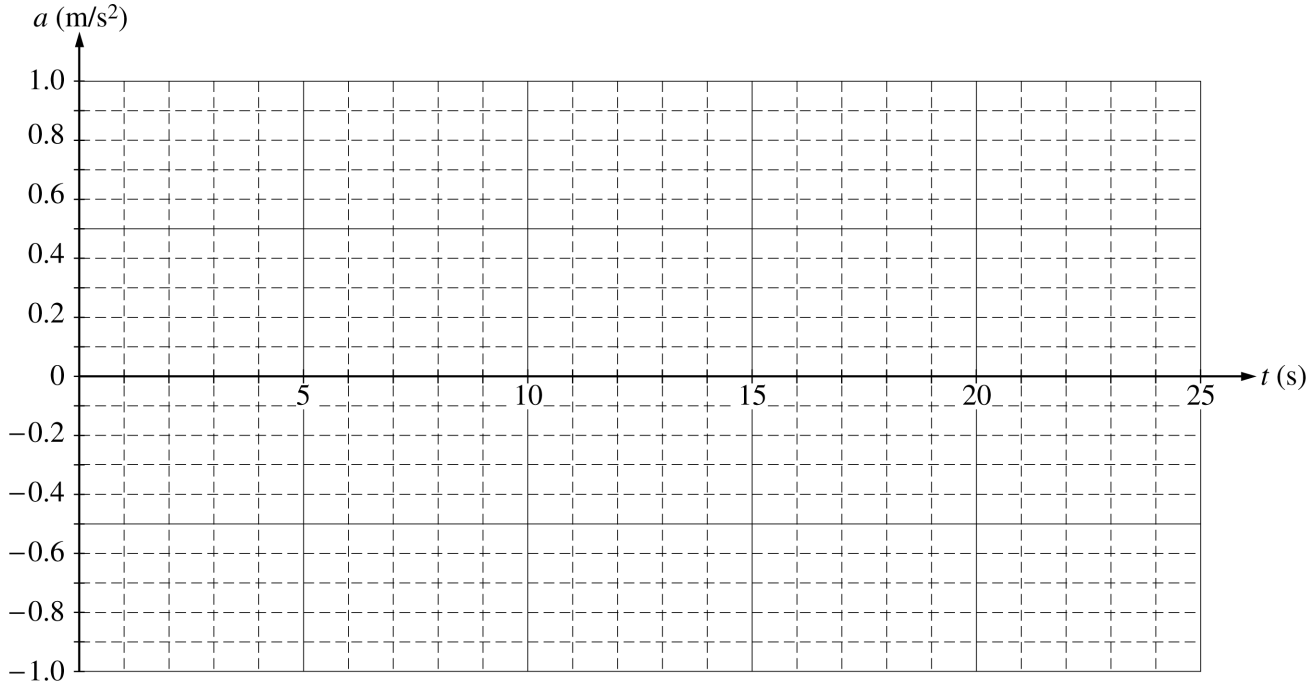
(d) On the axes below, sketch the acceleration a *versus* time t graph for the motion of the cart from $t = 0$ to $t = 25$ s.



(e) From $t = 25$ s until the cart reaches the end of the track, the cart continues with constant horizontal velocity. The cart leaves the end of the track and hits the floor, which is 0.40 m below the track. Neglecting air resistance, determine each of the following.

i. The time from when the cart leaves the track until it first hits the floor

ii. The horizontal distance from the end of the track to the point at which the cart first hits the floor

iii. The kinetic energy of the cart immediately before it hits the floor

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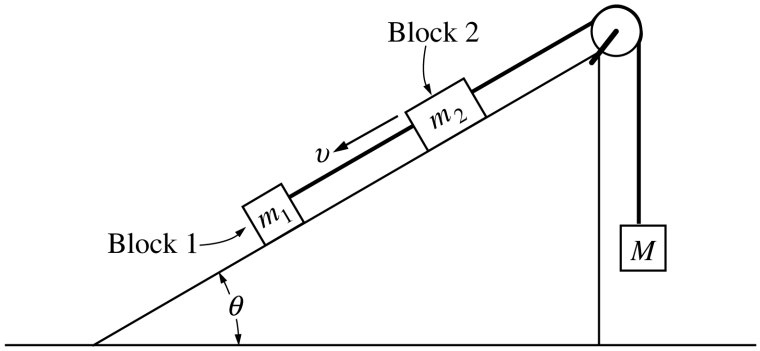
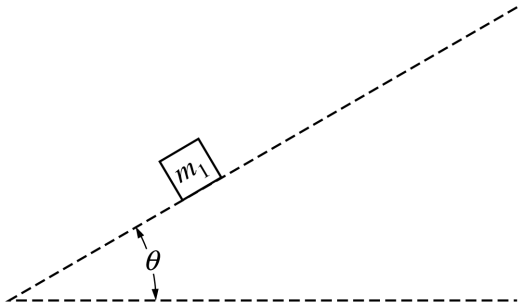


2. (15 points)

Blocks 1 and 2 of masses m_1 and m_2, respectively, are connected by a light string, as shown above. These blocks are further connected to a block of mass M by another light string that passes over a pulley of negligible mass and friction. Blocks 1 and 2 move with a constant velocity v down the inclined plane, which makes an angle θ with the horizontal. The kinetic frictional force on block 1 is f and that on block 2 is $2f$.

(a) On the figure below, draw and label all the forces on block m_1.

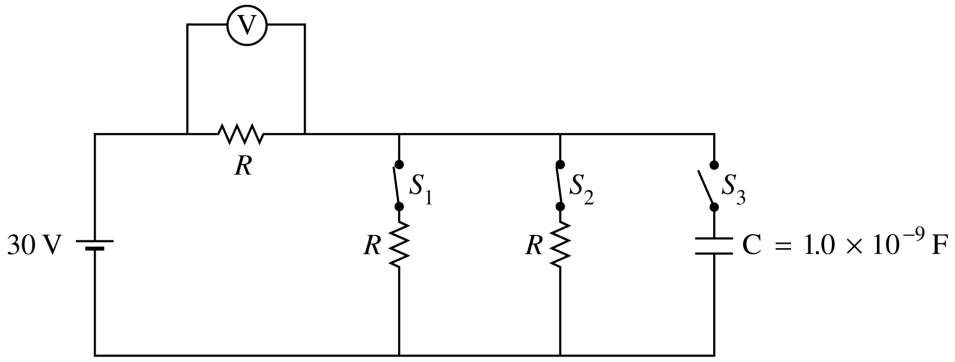


Express your answers to each of the following in terms of m_1, m_2, g, θ, and f.

(b) Determine the coefficient of kinetic friction between the inclined plane and block 1.

(c) Determine the value of the suspended mass M that allows blocks 1 and 2 to move with constant velocity down the plane.

(d) The string between blocks 1 and 2 is now cut. Determine the acceleration of block 1 while it is on the inclined plane.



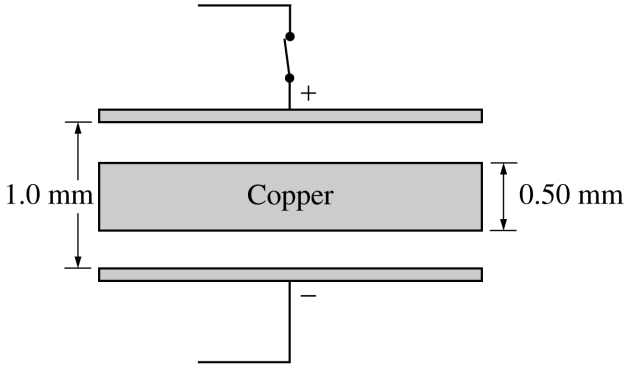
3. (15 points)

Three identical resistors, each with resistance R, and a capacitor of 1.0×10^{-9} F are connected to a 30 V battery with negligible internal resistance, as shown in the circuit diagram above. Switches S_1 and S_2 are initially closed, and switch S_3 is initially open. A voltmeter is connected as shown.

(a) Determine the reading on the voltmeter.

(b) Switches S_1 and S_2 are now opened, and then switch S_3 is closed. Determine the charge Q on the capacitor after S_3 has been closed for a very long time.

After the capacitor is fully charged, switches S_1 and S_2 remain open, switch S_3 remains closed, the plates are held fixed, and a conducting copper block is inserted midway between the plates, as shown below. The plates of the capacitor are separated by a distance of 1.0 mm, and the copper block has a thickness of 0.5 mm.



(c) i. What is the potential difference between the plates?

ii. What is the electric field inside the copper block?

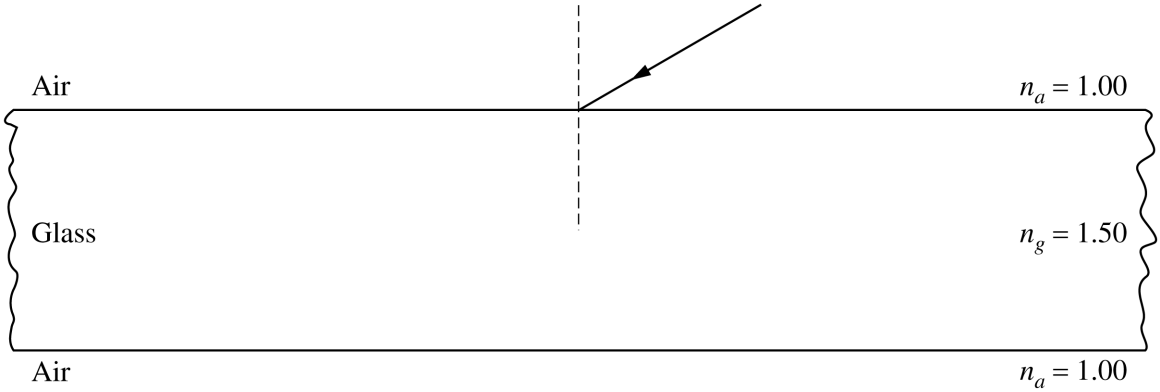
iii. On the diagram above, draw arrows to clearly indicate the direction of the electric field between the plates.

iv. Determine the magnitude of the electric field in each of the spaces between the plates and the copper block.

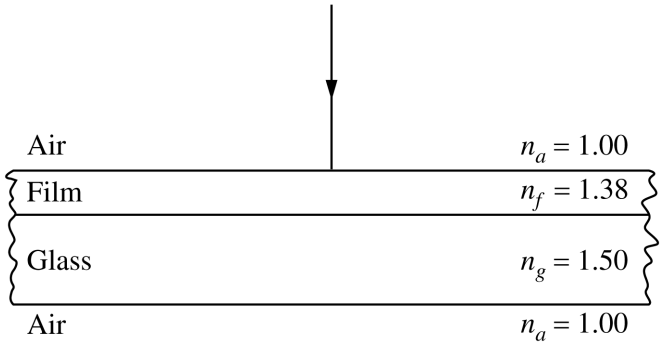
4. (15 points)

A sheet of glass has an index of refraction $n_g = 1.50$. Assume that the index of refraction for air is $n_a = 1.00$.

(a) Monochromatic light is incident on the glass sheet, as shown in the figure below, at an angle of incidence of 60°. On the figure, sketch the path the light takes the first time it strikes each of the two parallel surfaces. Calculate and label the size of each angle (in degrees) on the figure, including angles of incidence, reflection, and refraction at each of the two parallel surfaces shown.



(b) Next a thin film of material is to be tested on the glass sheet for use in making reflective coatings. The film has an index of refraction $n_f = 1.38$. White light is incident normal to the surface of the film as shown below. It is observed that at a point where the light is incident on the film, light reflected from the surface appears green ($\lambda = 525$ nm).

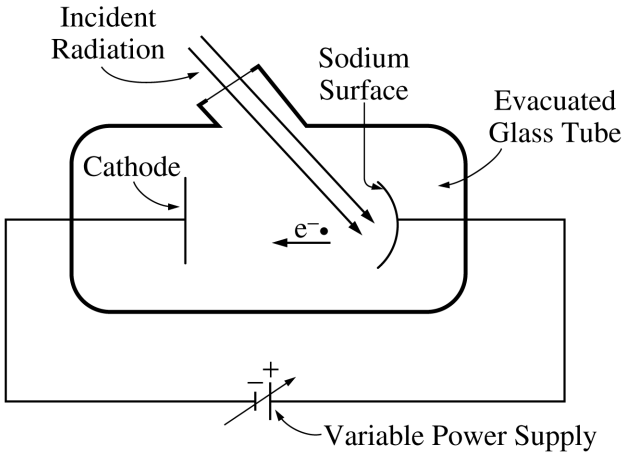


i. What is the frequency of the green light in air?

ii. What is the frequency of the green light in the film?

iii. What is the wavelength of the green light in the film?

iv. Calculate the minimum thickness of film that would produce this green reflection.



5. (10 points)

A sodium photoelectric surface with work function 2.3 eV is illuminated by electromagnetic radiation and emits electrons. The electrons travel toward a negatively charged cathode and complete the circuit shown above. The potential difference supplied by the power supply is increased, and when it reaches 4.5 V, no electrons reach the cathode.

(a) For the electrons emitted from the sodium surface, calculate the following.

i. The maximum kinetic energy

ii. The speed at this maximum kinetic energy

(b) Calculate the wavelength of the radiation that is incident on the sodium surface.

(c) Calculate the minimum frequency of light that will cause photoemission from this sodium surface.

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6. (10 points)

You are to design a procedure to determine experimentally the specific heat of an unknown liquid. You may not damage or destroy any equipment you use, and your method must be feasible and practical.

(a) List the equipment you would need. Include a labeled diagram.

(b) Describe the measurements you would make. Assign each measurement a symbol (such as time = t).

(c) Show explicitly using equations how the measured quantities would be used to determine the specific heat of the unknown liquid.

(d) Indicate one possible source of experimental error and discuss how it would affect your value for the specific heat. Justify your answer.

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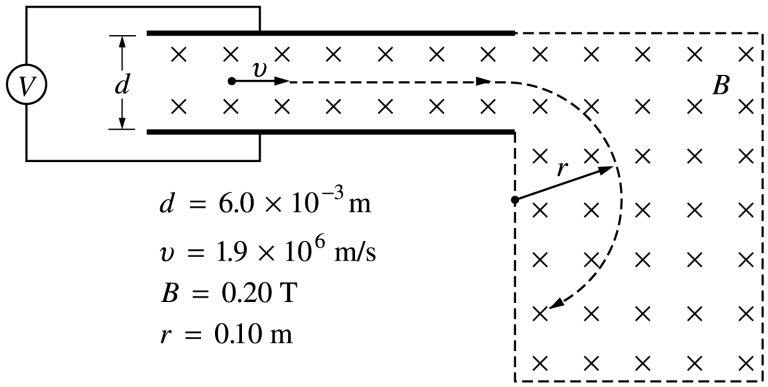

7. (10 points)

A particle with unknown mass and charge moves with constant speed $v = 1.9 \times 10^6$ m/s as it passes undeflected through a pair of parallel plates, as shown above. The plates are separated by a distance $d = 6.0 \times 10^{-3}$ m, and a constant potential difference V is maintained between them. A uniform magnetic field of magnitude $B = 0.20$ T directed into the page exists both between the plates and in a region to the right of them as shown. After the particle passes into the region to the right of the plates where only the magnetic field exists, its trajectory is circular with radius $r = 0.10$ m.

(a) What is the sign of the charge of the particle? Check the appropriate space below.

__ Positive __ Negative __ Neutral __ It cannot be determined from this information.

Justify your answer.

(b) On the diagram above, clearly indicate the direction of the electric field between the plates.

(c) Determine the magnitude of the potential difference V between the plates.

(d) Determine the ratio of the charge to the mass (q/m) of the particle.

END OF EXAMINATION