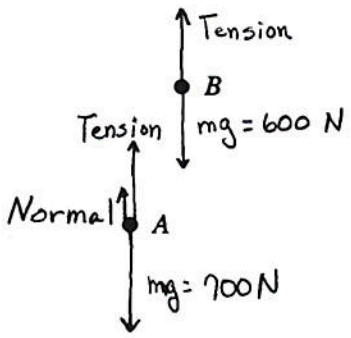
AP® PHYSICS B
2003 SCORING GUIDELINES

Question 1

15 points total

Distribution of points

(a) 3 points



For a free body diagram that includes any one of the three forces on Student A (weight, normal, or tension) — 1 point

For correctly including the other two forces on Student A — 1 point

For a correct free-body diagram for Student B (including both weight and tension) — 1 point

One point was deducted for each extraneous vector, up to a maximum of the number of point already earned

(b) 3 points

For equating the tension in the rope to the weight of Student B — 1 point

$T = m_B g$

For a correct expression for the sum of the forces on Student A — 1 point

$\Sigma F_A = T + N - m_A g = 0$

Eliminating T and solving for N

$N = m_A g - m_B g$

$N = (70\ \text{kg} - 60\ \text{kg})(9.8\ \text{m/s}^2) = 686\ \text{N} - 588\ \text{N}$

For the correct answer — 1 point

$N = 98\ \text{N}$ (or 100 N using $g = 10\ \text{m/s}^2$)

Question 1 (continued)

Distribution of points

(c) 3 points

For applying Newton's 2nd law to Student B — 1 point
$\Sigma F_B = m_B a$

For a correct expression for the sum of the forces on Student B — 1 point
$\Sigma F_B = T - m_B g$

Solving for T and substituting:
$T = m_B g + m_B a = 588 \text{ N} + (60 \text{ kg})(0.25 \text{ m/s}^2)$

For the correct answer — 1 point
$T = 603$ N (or 615 N using $g = 10 \text{ m/s}^2$)

(d) 2 points

For a correct response of "No" — 1 point
For a reasonable explanation — 1 point
Example: To lift student A off the floor, the tension must be greater than the students' weight of (70 kg)g

An answer of "Yes" was acceptable IF the answer to (c) was greater than the weight of Student A AND the justification was consistent.

(e) 3 points

For applying Newton's 2nd Law to Student B — 1 point
$\Sigma F_B = m_B a$

For a correct expression for the sum of the forces on Student B — 1 point
$\Sigma F_B = T - m_B g$

Solving for a

$$a = \frac{T}{m_b} - g$$

The minimum tension required to lift Student A is the student's weight
Substituting:

$$a = \frac{686 \text{ N}}{60 \text{ kg}} - 9.8 \text{ m/s}^2$$

For the correct answer — 1 point
$a = 1.63 \text{ m/s}^2$ (or 1.67 m/s^2 using $g = 10 \text{ m/s}^2$)

For indicating correct units in parts (b), (c) and (e) — 1 point

Solution

Distribution of Points

1. a) 6 points

The frictional force f is related to the normal force N between block and surface by $f = \mu N$ — 1 point

In this case, $N = mg$, and so — 1 point

$f = \mu mg = (0.2)(10)(10) = 20$ newtons — 2 points

For motion with constant velocity, the total force must be zero, so the force F must equal the frictional force in magnitude:
$F = f = 20$ newtons — 2 points

b) 5 points

By the work-energy theorem,
$\Delta K = F_{net} \cdot d$ — 2 points

The *net* force is therefore

$$F_{net} = \frac{\Delta K}{d} = \frac{60\ J}{4\ m} = 15 \text{ newtons}$$ — 1 point

The net force is the resultant of F′ and the frictional force f:
$F_{net} = F' - f$ — 1 point

So $F' = F_{net} + f = 20\ N + 15\ N = 35$ newtons — 1 point

c) 4 points

By Newton's second law, the acceleration is

$$a = \frac{F_{net}}{m}$$ — 1 point

The net force, found in part (b), is
15 newtons — 1 point

Hence, $a = \frac{15\ N}{10\ kg} = 1.5 \frac{m}{s^2}$ — 2 points

Total 15 points

Alternative approach to (b) and (c):

Alternate Points

The kinetic energy increase of 60 joules implies that

$\frac{1}{2}mv^2 - \frac{1}{2}mv_o^2 = 60$ joules — (2 points)

so that $v^2 - v_o^2 = \frac{2}{m} \cdot 60 = \frac{60}{5} = 12(m/s)^2$ — (1 point)

From constant-acceleration kinematics
$v^2 - v_o^2 = 2ad$ — (1 point)

and so

$$a = \frac{v^2 - v_o^2}{2d} = \frac{12}{2 \cdot 4} = 1.5\ m/s^2$$ — (1 point)

The net force is $F_{net} = F' - f$ — (1 point)

so from Newton's second law
$F' - f = ma$ — (1 point)

Hence $F' = f + ma = 20 + 10(1.5) = 35$ newtons — (2 points)

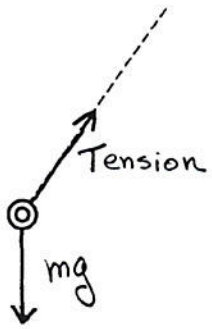
AP® PHYSICS B
2003 SCORING GUIDELINES (Form B)

Question 1

15 points total

Distribution of points

(a) 3 points



One point for each correctly drawn and appropriately labeled force — 2 points
For no incorrect forces — 1 point

(b) 5 points

For use of the correct equation relating acceleration and velocity — 1 point
$\mathbf{a} = \Delta\mathbf{v}/t$

For correctly calculating the magnitude of the acceleration — 1 point
$a = \dfrac{65\ \text{m/s} - 0}{30\ \text{s}} = \dfrac{13}{6}\ \text{m/s}^2$ (or $2.17\ \text{m/s}^2$)

For using an equation relating distance and acceleration — 1 point
$d = d_0 + v_0 t + \dfrac{1}{2}at^2$ OR $v^2 = v_0^2 + 2a\,\Delta d$

For substituting the calculated acceleration — 1 point
$d = \dfrac{1}{2}\left(\dfrac{13}{6}\ \text{m/s}^2\right)(30\ \text{s})^2$ OR $d = (65\ \text{m/s})^2 \Big/ 2\left(\dfrac{13}{6}\ \text{m/s}^2\right)$

For the correct answer — 1 point
$d = 975\ \text{m}$

Alternate solution — *Alternate points*

For use of the correct equation for average speed — *1 point*
$v_{\text{avg}} = (v_f + v_0)/2$

For correctly calculating the average speed — *1 point*
$v_{\text{avg}} = (65\ \text{m/s} + 0)/2 = 32.5\ \text{m/s}$

For using the appropriate equation relating distance to speed — *1 point*
$d = v_{\text{avg}} t$

For substituting v_{avg} into the equation — *1 point*
$d = (32.5\ \text{m/s})(30\ \text{s})$

For the correct answer — *1 point*
$d = 975\ \text{m}$

Question 1 (continued)

Distribution of points

(c) 5 points

For using the correct x and y components of the tension
$T_x = T\sin\theta$ and $T_y = T\cos\theta$ — 1 point

For the correct equation relating the forces along the x-axis
$T\sin\theta = ma$ — 1 point

For the correct equation relating the forces along the y-axis
$T\cos\theta = mg$ — 1 point

For combining these two equations to eliminate the tension
$\tan\theta = a/g$
$\tan\theta = (2.17\ \text{m/s}^2)/(9.8\ \text{m/s}^2)$ — 1 point

For the correct answer
$\theta = 12.5°$ (or $12.2°$ using $g = 10\ \text{m/s}^2$) — 1 point

(d) 2 points

For indicating that one would need to know the mass of the airplane, with some attempt to give an explanation that relates to the mass. — 1 point

For a correct explanation — 1 point
Example: The kinetic energy is the only form of mechanical energy in this case. The velocity is known, but you need the mass to calculate the kinetic energy.

SOLUTIONS

1990 Physics B

Distribution of points

1.

(a) 3 points

For some statement of conservation of momentum:

$p_i = p_f$ — 1 point

For correct expression for momentum: $p = mv$ — 1 point

$mv_0 = 101\ mv_f$

$v_f = \frac{v_0}{101}$ — 1 point

(b) 4 points

For correct general expression for kinetic energy: $K = \frac{1}{2}mv^2$ — 1 point

$K_i = \frac{1}{2}mv_0^2$

$K_f = \frac{1}{2}(101\ m)\left(\frac{v_0}{101}\right)^2$ — 1 point

For calculating the difference between kinetic energies:

$\Delta K = K_f - K_i$ — 1 point

(If this equation was not written, the point was awarded if a negative sign appeared in the final answer or some other indication of energy <u>loss</u> was made.)

$\Delta K = -\frac{50}{101}\ mv_0^2$ — 1 point

(c) 4 points

$x = vt$ — 1 point

$h = \frac{1}{2}gt^2$ — 1 point

Solving for t in terms of h:

$t = \sqrt{\frac{2h}{g}}$ — 1 point

Substituting t and speed from part (a) into equation for x:

$x = \frac{v_0}{101}\sqrt{\frac{2h}{g}}$ — 1 point

Distribution of points

(d) 2 points

Time t is the same. 1 point

For any reasonable justification 1 point

Example:
The vertical motion is independent of the horizontal motion. Therefore, the time of fall depends only on h and g, which are unchanged.

One point was awarded for any wrong answer with a justification that is not unreasonable. For example: t is longer because there is more air resistance on the block when it has a hole in it.

(e) 2 points

Distance x is less. 1 point

For any reasonable justification 1 point

Example:
Conservation of momentum requires that the momentum of the bullet be greater and the momentum of the block be less than when the bullet is embedded in the block and they both have the same speed. If the momentum of the block is less, then the speed v is less, but the time t remains the same. Therefore the distance $x = vt$ is also less than before.

2.

(a) 3 points

$E = \frac{V}{d}$ 1 point

$E = \frac{200\ \text{V}}{0.01\ \text{m}} = 2 \times 10^4\ \frac{\text{V}}{\text{m}}$ 1 point

For correctly indicating that the electric field points toward the bottom of the page 1 point

(b) 3 points

$F = ma$ 1 point

$F = qE$ 1 point

$a = \frac{qE}{m} = \frac{(1.6 \times 10^{-19}\ \text{C})(2 \times 10^4\ \text{V/m})}{9.1 \times 10^{-31}\ \text{kg}} = 3.5 \times 10^{15}\ \text{m/s}^2$, upward 1 point

AP® PHYSICS B
2002 FORM B SCORING GUIDELINES

Question 1

15 points total — **Distribution of points**

(a) 4 points

For any statement indicating that impulse equals change in momentum — 1 point

For any statement indicating that impulse can be determined from the area under the graph — 1 point

$\Delta p = F\Delta t$ = area under the curve

$$\Delta p = 2\left(\frac{1}{2}\right)\left(0.5\times10^{-3}\text{ s}\right)\left(10\times10^{3}\text{ N}\right) = 5\text{ N}\cdot\text{s}$$

For recognizing that the impulse on the 2 kg cart is negative, and subtracting it from the initial momentum of the cart — 1 point

$$p_{2\text{ kg after}} = (2.0\text{ kg})(3.0\text{ m/s}) - 5\text{ N}\cdot\text{s} = 1\text{ N}\cdot\text{s}$$

$$p_{2\text{ kg after}} = (2\text{ kg})v_{2\text{ kg after}} = 1\text{ N}\cdot\text{s}$$

For the correct answer — 1 point

$v_{2\text{ kg after}} = 0.5$ m/s to the right

(b) 3 points

For any statement of conservation of momentum — 1 point

$$p_{2\text{ kg before}} = p_{2\text{ kg after}} + p_{m\text{ after}}$$

For correct substitutions — 1 point

$$6\text{ N}\cdot\text{s} = 1\text{ N}\cdot\text{s} + m(1.6\text{ m/s})$$

For the correct answer — 1 point

$m = 3.1$ kg

Alternate solution — *Alternate points*

The average acceleration is the average force divided by the mass

$\bar{a} = \bar{F}/m$

For calculating the average acceleration — *1 point*

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{1.6\text{ m/s}}{1\times10^{-3}\text{ s}} = 1600\text{ m/s}^2$$

For calculating the average force — *1 point*

$$\bar{F} = \frac{1}{2}(0 + 10{,}000)\text{ N} = 5000\text{ N}$$

$$m = (5000\text{ N})/(1600\text{ m/s}^2)$$

For the correct answer — *1 point*

$m = 3.1$ kg

Note: An alternate solution is to do part (b) first using impulse, in which case the first two points noted above for part (a) could be earned. Then conservation of momentum can be used to solve part (a), so the first point noted above for part (b) could be earned.

Question 1 (cont'd.)

Distribution of points

(c) 2 points

For using the slope of the graph to determine the acceleration — 1 point

$a = \text{slope} = \dfrac{(0.5 - 1.6)\ \text{m/s}}{(3.5 - 2)\ \text{s}}$

For the correct answer — 1 point

$a = -0.73\ \text{m/s}^2$

(d) 3 points

For using the area under the curve or one of the equations $d = vt$ or $d = \bar{v}t$ — 1 point

For calculating a distance for each segment of the graph — 1 point

$d_1 = (1.6\,\text{m/s})(2\ \text{s}) = 3.2\ \text{m}$

$d_2 = \dfrac{(1.6 + 0.5)\ \text{m/s}}{2}(1.5\ \text{s})$ or $(1.6\ \text{m/s})(1.5\ \text{s}) + \dfrac{1}{2}\left(-0.73\ \text{m/s}^2\right)(1.5\ \text{s})^2$

$d_2 = 1.6\ \text{m}$

$d_3 = (0.5\ \text{m/s})(1.5\ \text{s}) = 0.8\ \text{m}$

$d_{\text{tot}} = d_1 + d_2 + d_s$

For the correct answer — 1 point

$d_{\text{tot}} = 5.5\ \text{m}$

(e) 3 points

The acceleration is negative, so the cart must be moving opposite to the force of gravity, which is the only force acting on it.

For indicating that the ramp goes up — 1 point

For using conservation of energy — 1 point

$mgh = \dfrac{1}{2}m\left(v_i^2 - v_f^2\right)$

$h = \dfrac{1}{2\left(10\ \text{m/s}^2\right)}\left((1.6\ \text{m/s})^2 - (0.5\ \text{m/s})^2\right)$

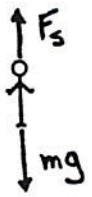
For the correct answer — 1 point

$h = 0.12\ \text{m}$

1.

Note: To facilitate grading of this question, 30 points were counted and the total was divided by 2, with half points rounded up.

(a) 4 points



1 point for each vector drawn in the correct direction — 2 points

For correct labels on both vectors (e.g. F_s, F_n, F_e, and W, mg, gravity) — 1 point

For no extraneous vectors — 1 point

(b) i. 6 points

For any statement of Newton's Second Law:

$\sum F = ma$ — 1 point

The mass of the student is found by applying this law to the student's weight, where $a = g$:

$$m = \frac{F}{a} = \frac{W}{g} = \frac{500 \text{ N}}{10 \text{ m/s}^2} = 50 \text{ kg}$$

For the correct expression for the net force on the student:

$F_s - mg = ma$ — 1 point

The upward force F_s exerted on the student by the scale is equal to the scale reading. For each time interval, applying Newton's Second Law to find the acceleration requires dividing the net force by the student's mass.

0-5 seconds: $a = \frac{500 \text{ N} - 500 \text{ N}}{50 \text{ kg}} = 0$ — 1 point

5-10 seconds: $a = \frac{700 \text{ N} - 500 \text{ N}}{50 \text{ kg}} = 4 \text{ m/s}^2$ — 1 point

10-15 seconds: $a = \frac{500 \text{ N} - 500 \text{ N}}{50 \text{ kg}} = 0$ — 1 point

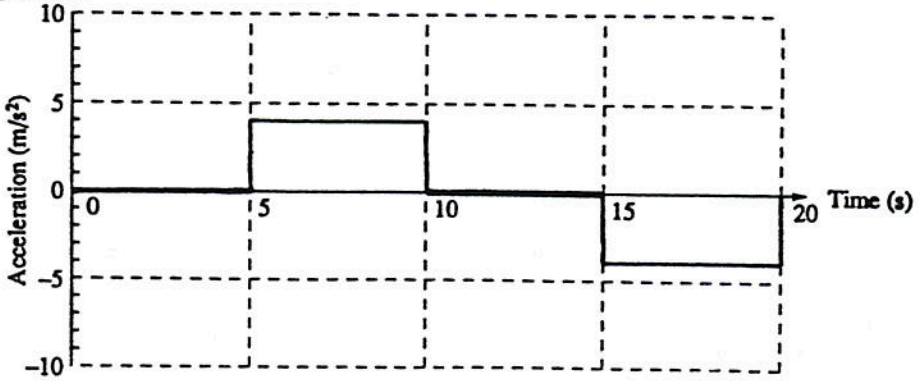
15-20 seconds: $a = \frac{300 \text{ N} - 500 \text{ N}}{50 \text{ kg}} = -4 \text{ m/s}^2$ — 1 point

(If all four values of acceleration were correct, credit was given for the first two points for the equations even if they were not written explicitly.)

Distribution of Points

1. (continued)

(b) ii. 2 points



For the correct shape of the graph (four horizontal segments, with correct two segments above and below the axis) — 1 point

For correctly graphing the magnitudes of the acceleration — 1 point

(c) i. 5 points

For the kinematic equation applicable for constant acceleration: $v = v_0 + at$ (addition of v_0 must be indicated) — 1 point

For each time interval, substitute the initial velocity for that interval, the appropriate acceleration from part (b), and a time of 5 seconds.

5 seconds: $v = 0 + (0)(5\text{ s}) = 0$ — 1 point

10 seconds: $v = 0 + (4\text{ m/s}^2)(5\text{ s}) = 20\text{ m/s}$ — 1 point

15 seconds: $v = 20\text{ m/s} + (0)(5\text{ s}) = 20\text{ m/s}$ — 1 point

20 seconds: $v = 20\text{ m/s} + (-4\text{ m/s}^2)(5\text{ s}) = 0$ — 1 point

(If all four values were correct credit was given for the equation even if it was not written explicity.)

(Alternate Solution) — (Alternate Points)

The change in velocity Δv for each interval is equal to the area under the a vs t graph.

For indicating that at the end of each interval $v = v_0 + \Delta v$ — (1 point)

5 seconds: $v = 0 + 0 = 0$ — (1 point)

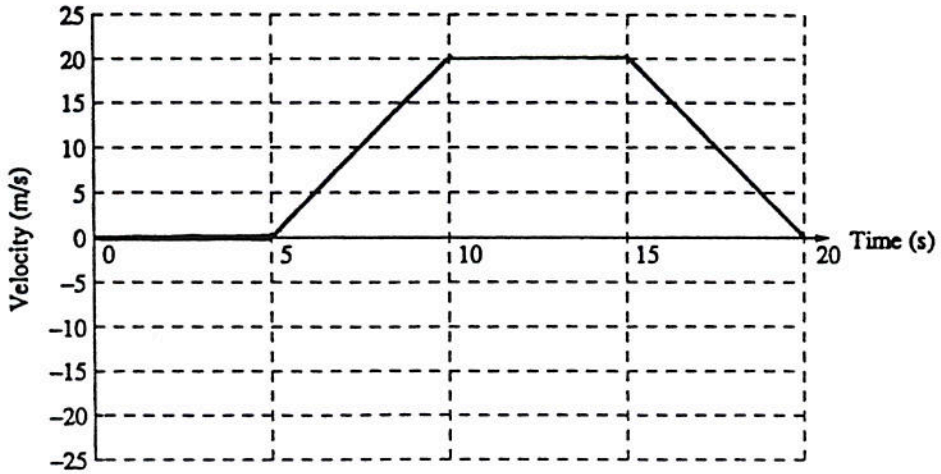
10 seconds: $v = 0 + (4\text{ m/s}^2)(5\text{ s}) = 20\text{ m/s}$ — (1 point)

15 seconds: $v = 20\text{ m/s} + 0 = 20\text{ m/s}$ — (1 point)

20 seconds: $v = 20\text{ m/s} + (-4\text{ m/s}^2)(5\text{ s}) = 0$ — (1 point)

Distribution of Points

1. (continued)
(c) ii. 4 points



1 point for each segment having the correct shape and slope (or which is consistent with graph in part (b)) — 4 points

(d) i. 5 points

For the kinematic equation applicable for constant acceleration, $x = x_0 + v_0 t + (1/2)at^2$ or equivalent — 1 point

For each time interval, substitute the initial position for that interval, the initial velocity for that interval from part (c), the appropriate acceleration, and a time of 5 seconds.

5 seconds: $x = 0 + (0)(5\text{ s}) + (1/2)(0)(5\text{ s})^2 = 0$ — 1 point

10 seconds: $x = 0 + (0)(5\text{ s}) + (1/2)(4\text{ m/s}^2)(5\text{ s})^2 = 50\text{ m}$ — 1 point

15 seconds: $x = 50\text{ m} + (20\text{ m/s})(5\text{ s}) + (1/2)(0)(5\text{ s})^2 = 150\text{ m}$ — 1 point

20 seconds: $x = 150\text{ m} + (20\text{ m/s})(5\text{ s}) + (1/2)(-4\text{ m/s}^2)(5\text{ s})^2 = 200\text{ m}$ — 1 point

(If all four values were correct, credit was given for the equation even if it was not explicitly written.)

Distribution of Points

1. (continued)
(d) (continued)

(Alternate Solution) (Alternate Points)

The change in position Δx for each interval is equal to the area under the v vs. t graph.

For indicating that at the end of each interval $x = x_0 + \Delta x$ (1 point)

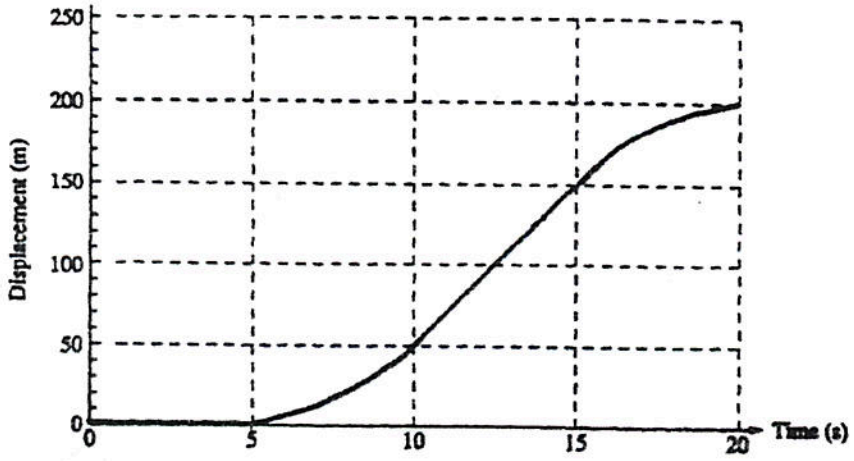
5 seconds: $x = 0 + 0 = 0$ (1 point)

10 seconds: $x = 0 + (1/2)(20\ m/s)(5\ s) = 50\ m$ (1 point)

15 seconds: $x = 50\ m + (20\ m/s)(5\ s) = 150\ m$ (1 point)

20 seconds: $x = 150\ m + (1/2)(20\ m/s)(5\ s) = 200\ m$ (1 point)

(d) ii. 4 points



1 point for each segment that has the correct shape and slope (or which is consistent with graph in part (c)) 4 points

To obtain final score, divide number of points by 2, rounding up any half point.