General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong — for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exams equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 1

10 points total | **Distribution of points**

(a) 2 points

For a correct conservation of energy equation for this situation — 1 point

$mgh_i = mgh_f + \frac{1}{2}mv_f^2$

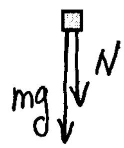
$v_f = \sqrt{2g\left(h_i - h_f\right)}$

$v_f = \sqrt{2\left(9.8\ \text{m/s}^2\right)(2.0\ \text{m} - 0.50\ \text{m})}$

For the correct answer — 1 point

$v_f = 5.4\ \text{m/s}$ (or 5.5 using $g = 10\ \text{m/s}^2$)

(b) 3 points



For correctly drawing and appropriately labeling the weight of the block — 1 point
For correctly drawing and appropriately labeling the normal force — 1 point
For no extraneous forces — 1 point

(c) 2 points

At the top of the track, the net force on the block is the centripetal force

$ma = mv^2/r = mg + N$

The condition for minimum speed is that the normal force is zero.
For a correct equation that can be solved for the minimum speed — 1 point

$mv_{\text{min}}^2/r = mg$

$v_{\text{min}} = \sqrt{rg}$

$v_{\text{min}} = \sqrt{(0.60\ \text{m})\left(9.8\,\text{m/s}^2\right)}$

For the correct answer — 1 point

$v_{\text{min}} = 2.4\ \text{m/s}$

Question 1 (continued)

	Distribution of points
(d) 3 points	
For a correct conservation of energy equation for this situation	1 point
$mgh_{min} = mg(2r) + \frac{1}{2}mv_{min}^2$	
$h_{min} = 2r + \left(v_{min}^2 / 2g\right)$	
For correctly substituting the value of v_{min} from part (c)	1 point
$h_{min} = 2(0.60\ \text{m}) + \left((2.4\ \text{m/s})^2 / 2\left(9.8\ \text{m/s}^2\right)\right)$	
For the correct answer	1 point
$h_{min} = 1.5\ \text{m}$	

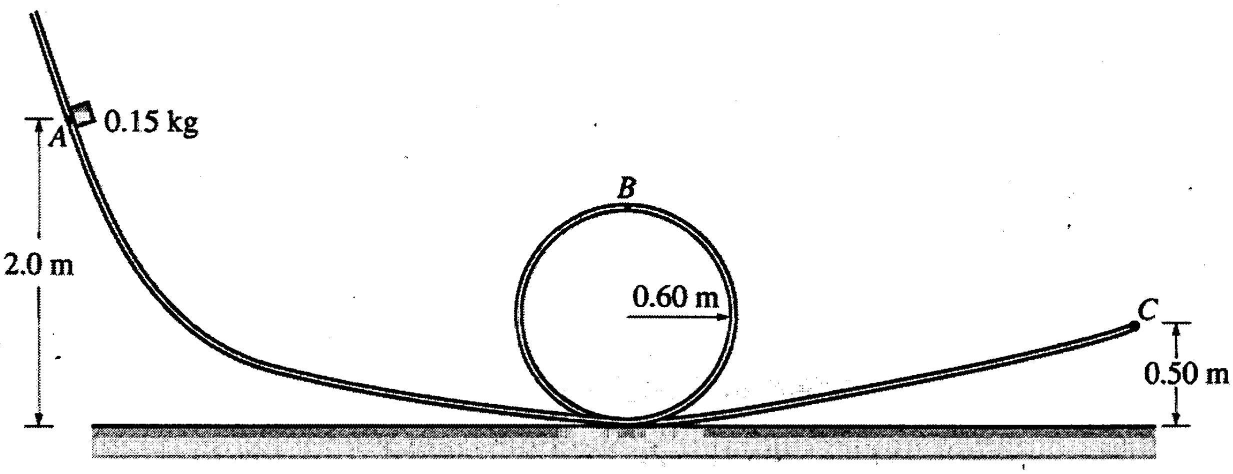
PHYSICS B

SECTION II

Time—90 minutes

7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 1 and 4-7 and about 17 minutes for answering each of Questions 2-3. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the lavender insert.



1. (10 points)

A small block of mass 0.15 kg is placed at point A at a height 2.0 m above the bottom of a track, as shown in the figure above, and is released from rest. It slides with negligible friction down the track, around the inside of the loop of radius 0.60 m, and leaves the track at point C at a height 0.50 m above the bottom of the track.

(a) Calculate the speed of the block when it leaves the track at point C.

$U_A = mgh = (0.15)(9.8)(2.0) = 2.9J$

$U_C = mgh = (0.15)(9.8)(0.50) = 0.74J$

$U_A + K_A = U_C + K_C$

$2.9 + 0 = 0.74 + K_C$

$K_C = 2.9 - 0.74 = 2.21J = 2.2J\ (2 s.f.)$

$2.2J = \frac{1}{2} m v_C^2$

$= \frac{1}{2}(0.15) v_C^2$

$v_C = 5.4 m/s$

(b) On the figure below, draw and label the forces (not components) that act on the block when it is at the top of the loop at point B.

FN = normal force of track on block

W = weight of block

(c) Calculate the minimum speed the block can have at point B without losing contact with the track.

B-1A-2

The minimum speed occurs when $F_N = 0$.

$$F_N + w = \frac{mv^2}{r}$$

$$0 + (0.15)(9.8) = \frac{(0.15)v^2}{0.60}$$

$$v = 2.4 \text{ m/s}$$

(d) Calculate the minimum height h_{min} above the bottom of the track at which the block can be released and still go around the loop without losing contact with the track.

In order for the block to not lose contact,

$$K_B = \frac{1}{2}mv_{min}^2 = \frac{1}{2}(0.15)(2.4)^2 = 0.44\text{ J}$$

$$U_A + K_A = U_B + K_B$$

$$mgh_A + 0 = mgh_B + 0.44$$

$$(0.15)(9.8)h_A = (0.15)(9.8)(1.2) + 0.44$$

$$h_A = 1.5\text{ m}$$

$$h_{min} = 1.5\text{ m}$$

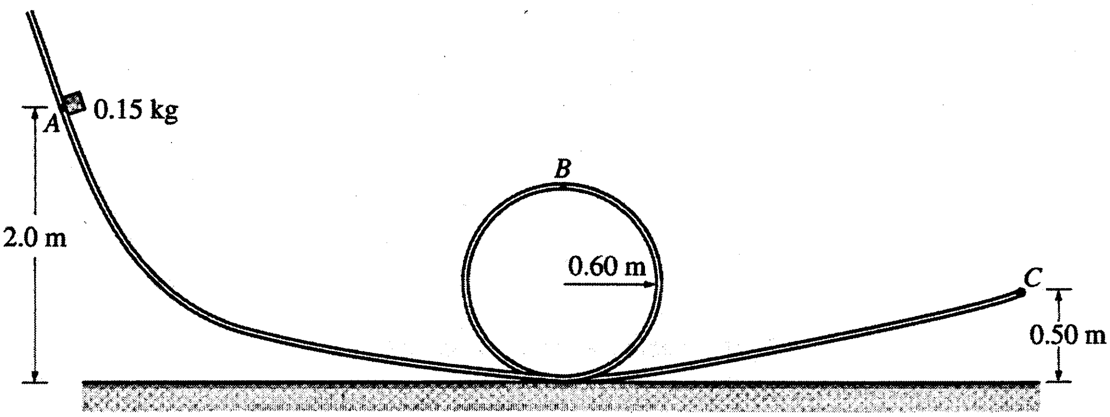
PHYSICS B

SECTION II

Time—90 minutes

7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 1 and 4-7 and about 17 minutes for answering each of Questions 2-3. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the lavender insert.



1. (10 points)

A small block of mass 0.15 kg is placed at point A at a height 2.0 m above the bottom of a track, as shown in the figure above, and is released from rest. It slides with negligible friction down the track, around the inside of the loop of radius 0.60 m, and leaves the track at point C at a height 0.50 m above the bottom of the track.

(a) Calculate the speed of the block when it leaves the track at point C.

Mechanical energy is conserved

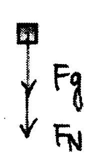
KE + PE = constant

~~$\frac{1}{2} \times 0.15 \times$~~ ~~$0.15 \times 9.8 \times 2.0 = 0.15 \times 9.8 \times 0.50 + \frac{1}{2} \times 0$~~

$0.15 \times 9.8 \times 2.0 = 0.15 \times 9.8 \times 0.50 + \frac{1}{2} \times 0.15 \times V_c^2$

$V_c = 5.4$ m/s

(b) On the figure below, draw and label the forces (not components) that act on the block when it is at the top of the loop at point B.



(c) Calculate the minimum speed the block can have at point B without losing contact with the track.

B-1B-2

~~$F_g + F_N = F_c$~~

~~$mg +$~~

~~$mgh_A = mgh_B$~~

~~$F_g + F_N = F_c$~~

~~$mg + \quad = \frac{mV_{Bmin}^2}{r}$~~

$F_g = F_c$

$2mg = \frac{mV^2}{r}$

$V = \sqrt{2gr}$

$= \sqrt{9.8 \times 0.60 \times 2}$

$= 3.4 \text{ m/s}^2$

(d) Calculate the minimum height h_{min} above the bottom of the track at which the block can be released and still go around the loop without losing contact with the track.

$mgh_{min} = mgh_B + \frac{1}{2} mV_{Bmin}^2$

$h_{min} = h_B + \frac{V_B^2}{2g}$

$= 2 \times 0.60 + \frac{3.4^2}{2 \times 9.8}$

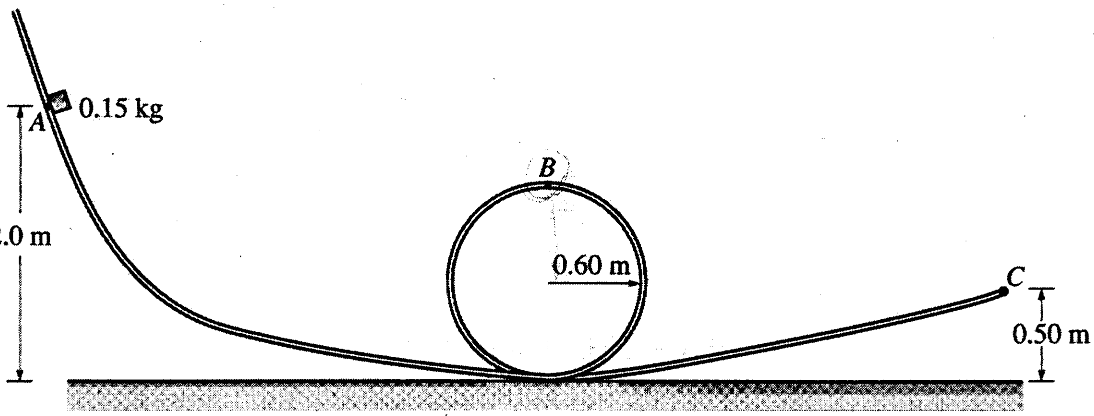
$= 1.2 + 0.59$

$= 1.8 \text{ m}$

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

B-1C-1

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 1 and 4-7 and about 17 minutes for answering each of Questions 2-3. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the lavender insert.



1. (10 points)

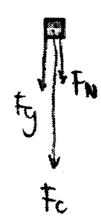
A small block of mass 0.15 kg is placed at point A at a height 2.0 m above the bottom of a track, as shown in the figure above, and is released from rest. It slides with negligible friction down the track, around the inside of the loop of radius 0.60 m, and leaves the track at point C at a height 0.50 m above the bottom of the track.

(a) Calculate the speed of the block when it leaves the track at point C.

At point A, the gravitational potential energy is $(0.15kg) \times (9.8 m/s^2) \times (2.0 m)$. At point C, the gravitational potential energy is $(0.15kg) \times (9.8 m/s^2) \times (0.5 m)$. The block slides with negligible friction. Thus, kinetic energy at point C equals to $(0.15 \times 9.8 \times 2.0 - 0.15 \times 9.8 \times 0.5) J$, which also equals to $\frac{1}{2} \times 0.15 \times v^2$.

$\therefore v = 5.42 m/s$

(b) On the figure below, draw and label the forces (not components) that act on the block when it is at the top of the loop at point B.



Fg ⇝ By the gravity

FN ⇝ By the track

Fc ⇝ By sliding around the inside of the loop.

(c) Calculate the minimum speed the block can have at point B without losing contact with the track.

B-1C-2

$F_c \geq F_N + F_g$ needs to be true in order to keep slide without losing contact with the track. $m\frac{v^2}{r} \geq mg + mg$

$\frac{v^2}{r} \geq 2g$, so $v^2 \geq 2rg$. Thus $v \geq 2\sqrt{2rg}$. ∴ $v \geq 2\sqrt{2 \times 0.6 \times 9.8}$

$v \geq 6.86$

∴ minimum speed = 6.86 m/s.

(d) Calculate the minimum height h_{min} above the bottom of the track at which the block can be released and still go around the loop without losing contact with the track.

$E_k + E_p = E_{mechanical}$

Question 1

Sample: B-1A
Score: 10

All parts are correct and earned full credit. Note that the student includes helpful explanatory notes regarding variable names and physical assumptions at various points.

Sample: B-1B
Score: 8

Parts (a) and (b) are correct and earned full credit. In part (c) the initial equation is incorrect, as it appears to double-count the gravitational force, so no credit was earned. In part (d) the calculation is correctly executed using a consistent substitution of the incorrect result from part (c), and so full credit was earned.

Sample: B-1C
Score: 4

Part (a) is correct and earned full credit. Part (b) earned 2 points for correctly showing the weight and normal force but did not earn the final point since an extraneous force is included. In part (c) an incorrect equation is derived when *mg* is substituted for the normal force instead of zero, so no credit was earned. No meaningful work is shown in part (d).