AP® Physics B
1999 Sample Student Responses

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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 this booklet in the spaces provided after each part, NOT in the green insert.

1. (15 points)
The Sojourner rover vehicle shown in the sketch above was used to explore the surface of Mars as part of the Pathfinder mission in 1997. Use the data in the tables below to answer the questions that follow.

Mars Data	
Radius:	0.53 × Earth's radius
Mass:	0.11 × Earth's mass

Sojourner Data	
Mass of Sojourner vehicle:	11.5 kg
Wheel diameter:	0.13 m
Stored energy available:	5.4×10^5 J
Power required for driving under average conditions:	10 W
Land speed:	6.7×10^{-3} m/s

(a) Determine the acceleration due to gravity at the surface of Mars in terms of g, the acceleration due to gravity at the surface of Earth.

Gravitational force: $\frac{Gm_1m_2}{r^2}$ m_2 is negligible

If mass is 0.11 times that of the Earth and radius is 0.53 times that of the Earth,

$g_m = \frac{0.11}{(0.53)^2} g = \boxed{0.392g.}$

(b) Calculate Sojourner's weight on the surface of Mars.

$w = mg = 11.5(0.392)(9.8) = \boxed{44.13\ N.}$

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(c) Assume that when leaving the Pathfinder spacecraft Sojourner rolls down a ramp inclined at 20° to the horizontal. The ramp must be lightweight but strong enough to support Sojourner. Calculate the minimum normal force that must be supplied by the ramp.

$N = w\cos\theta = (44.13)(\cos 20°) = \boxed{41.47\ N.}$

(d) What is the net force on Sojourner as it travels across the Martian surface at constant velocity? Justify your answer.

The net force is 0, for $\Sigma F = ma$, and since $a = 0$ because the Sojourner is traveling at constant velocity, $\Sigma F = 0$.

(e) Determine the maximum distance that Sojourner can travel on a horizontal Martian surface using its stored energy.

Length of time energy will last: $t = \frac{E}{P} = \frac{5.4\times10^5}{10} = 5.4\times10^4\ s.$

Distance:

$d = vt = (6.7\times10^{-3})(5.4\times10^4) = \boxed{361.8\ m.}$

(f) Suppose that 0.010% of the power for driving is expended against atmospheric drag as Sojourner travels on the Martian surface. Calculate the magnitude of the drag force.

0.01% of $P = 0.0001(10) = 0.001\ W.$

$P = Fv;\ F = \frac{P}{v};\ F = \frac{0.001}{6.7\times10^{-3}} = \boxed{0.149\ N.}$

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(a) Determine the acceleration due to gravity at the surface of Mars in terms of g, the acceleration due to gravity at the surface of Earth.

$F_G = (0.11)(g)$

$= 0.11g$

(b) Calculate Sojourner's weight on the surface of Mars.

$W = 0.11\,(11.5\,kg)(g)$

$= 12.4\,N$

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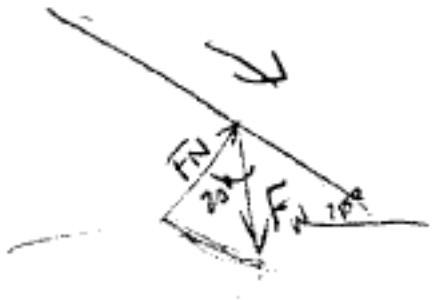
(c) Assume that when leaving the Pathfinder spacecraft Sojourner rolls down a ramp inclined at 20° to the horizontal. The ramp must be lightweight but strong enough to support Sojourner. Calculate the minimum normal force that must be supplied by the ramp.

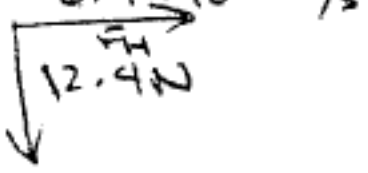


$\cos 20 = \frac{F_N}{F_W}$

$= \frac{F_N}{12.4N}$

$F_N = 11.6N$ perpendicular to the ramp

(d) What is the net force on Sojourner as it travels across the Martian surface at constant velocity? Justify your answer.



$a = 0$

$F_N = 0(11.5kg)$

$= 0$

acceleration is 0 since velocity is constant

The net force is ON since the velocity is constant and $F = ma$ where acceleration is $0 m/s^2$

(e) Determine the maximum distance that Sojourner can travel on a horizontal Martian surface using its stored energy.

$P = FV$ $W = Fd$ $\frac{kg\,m}{s^2} \cdot \frac{m}{s}$ $\frac{kg\,m^2}{s^3}$

$10W = 6.7 \times 10^{-3}\ m/s \cdot F$

$5.4 \times 10^5 J = 1492.537N \times d$

$F = 1492.537N$

$d = 3.618 \times 10^2\ m$

(f) Suppose that 0.010% of the power for driving is expended against atmospheric drag as Sojourner travels on the Martian surface. Calculate the magnitude of the drag force.

$0.010\% = \frac{0.010}{100} = 1 \times 10^{-4}$

Power for drag $= (1 \times 10^{-4})$ (total power)

$= (1 \times 10^{-4})(10W)$

$= 1 \times 10^{-3} W$

$V = 6.7 \times 10^{-3}\ m/s$

$P = FV$

$1 \times 10^{-3} W = F(6.7 \times 10^{-3}\ m/s)$

$F = 1.49 \times 10^{-1} N$

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