ExI Solutions p1 of 10 (X4)

[Re-scanned 10/10/03 to correct Problem #20: time is 3 seconds, not 30 seconds and Problem #17b: time is 0.40 sec, not 0.80 sec.]

Exam I: Physics 121 F03
October 3, 2003

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Exam I, Part I: Multiple Choice

This Part I of Exam I consists of 16 parts worth 6 points each and comprises 80% of the full exam. For each problem fill in the circle next to the letter of your chosen answer on the NCS answer sheet using a #2 pencil, making sure that the number of the line corresponds to the number of the problem you are answering. There is only one correct answer for each problem, and no subtractions will be made for wrong answers.
Use only lines 1 through 16 on the NCS sheet.

1. Which of the equations below is dimensionally incorrect?
Insert the letter of your chosen answer into your NCS answer sheet.

a. $v^2 = v_0^2 + 2ax$
b. $a = a_0 + v/t$
c. $v = x/t$
d. $x/y = \cos\theta$
e. $x(t) = x_0 + v_0 t^2$

a) $(L/T)^2 = (L/T)^2 + 2(L/T^2)L$ (ok)
b) $L/T^2 = L/T^2 + (L/T)/T$ (ok)
c) $L/T = L/T$ (ok)
d) L/L = dimensionless (ok)
e) $L = L + \frac{L}{LT} \cdot T^2$ WRONG!

(e) is the correct choice because its dimensions are inconsistent

2. Modern electroplaters can cover a surface area of 60.0 m^2 with one troy ounce of gold (volume = 1.611 cm^3).
What is most nearly the thickness of the electroplated gold?

a. 2.68×10^{-7} m
b. 1.34×10^{-9} m
c. 2.6×10^{-6} m
d. 3.33×10^{-7} m
e. 2.7×10^{-8} m

$V = 1.611 = A \cdot t \Rightarrow t = V/A = \frac{1.611 \times 10^{-6} m^3}{60\ m^2} = 2.7 \times 10^{-8}$ m

(e)

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3. Suppose that 2 macrometoerites per century strike each square meter of the surface of some distant moon, and that each a sphere of radius 0.3 mm. Given that a year is about 3×10^7 s, how many seconds would it take to cover the moon's surface with meteorites up to a depth of 40 cm?

a) 10^{27} s
b) 10^{24} s
c) 10^{21} s
d) 10^{18} s
e) 10^{15} s

On each m^2 of moon need to supply a volume $V = (0.4)\cdot 1m^2 = 0.4m^3 = Ah$ w. $A = 1m^2$

Each MacroM has a volume of $v \sim (0.6mm)^3 = d^3 \approx 0.216 \times (10^{-3})^3 m^3 = 2.2\times10^{-10} m^3$

Then need $N = V/v$ Macrometerites/m^2. At rate $R = \frac{2}{100} yr\, m^2 = \frac{2\times10^{-2}}{yr\cdot m^2} \cdot \frac{1yr}{3\times10^7 sec}$

we accumulate $n(t) = Rt$ $= 0.67\times10^{-9}/sec\cdot m^2$.

Then if T is time to accumulate $N = V/v$ MacroMs, then $N = RTA$

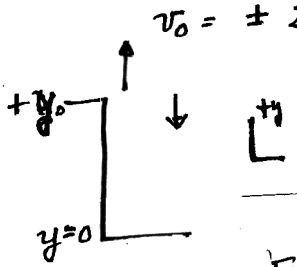
and $T = N/RA = V/RvA = \frac{0.4m^3}{2.2\times10^{-10}m^3} \times \frac{sec\, m^2}{0.67\times10^{-9}\cdot(1m^2)}$ where $A = 1m^2$

$= 0.3\times10^{10+9} \approx \boxed{10^{18} sec}$ (d) is correct

4. Maria throws two stones from the top edge of a building with a speed of 20 m/s. She throws one straight down and the other straight up. The first one hits the street in a time t_1. How much later is it before the second stone hits, most nearly?

a. 5 s
b. 4 s
c. 3 s
d. 2 s
e. 1 s

$v_0 = \pm 20$ m/sec.



Stone launched upward at +20 m/sec slows as it rises reaching zero velocity at its highest point at $t_2 = v_0/g$ after launch. It then begins to fall and after t_2 seconds passes the launch point with velocity $-v_0 = -20$ m/sec.

From there it takes t_1 more seconds to fall, – the same as the rock launched with $v_0 = -20$ sec at the start.

Then $T_{up} = t_2 + t_2 + t_1$ is greater than t_1 by $2t_2 = 2v_0/g$ *

$\Delta t = T_{up} - t_1 = 2t_2 = 2v_0/|g| = \boxed{4.1 sec}$ (b) is correct

{Note * $v(t_2) = v_0 + gt_2 = 0$ specifies t_2 take $t_2 = \frac{-v_0}{g} = \frac{20}{9.8} = 2.05$}

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5. A parachutist jumps out of an airplane and accelerates with gravity to a maximum velocity of 58.8 m/s in 6.00 seconds. She then pulls the parachute cord and after a 4.00–second constant deceleration, descends at 10.0 m/s for 60.0 seconds, reaching the ground. From what height did the parachutist jump, most nearly?

a. 914 m
b. 1130 m
c. 1520 m
d. 1750 m
e. 1843 m

(1) $0 < t < 6.00$ constant acceleration is $g = -9.80\ m/sec^2$ and $\Delta y = -h_1$

(2) $6.00 < t < 10\ sec$ " deceleration from $58.8\ m/sec$ to $10\ m/sec$ & $\Delta y = -h_2$

(3) $10 < t < 70\ sec$ constant velocity of $-10.0\ m/sec$. & $\Delta y = -h_3$

Then Height $H = |h_1| + h_2 + h_3$, where $|h_1| = \frac{1}{2}|g|t^2 = \frac{36}{2}(9.80) = 176.4\ m$.

h_2 is distance travelled in 4 sec: $\Delta y_2 = v_0 t + \frac{1}{2}a_2 t^2 = (-58.8)(4) + \frac{1}{2}(12.2)(16)$

while $a_2 = \frac{-10\ m/s + 58.8}{4} = +12.2\ m/sec^2$

$= -235.2 + 97.6$

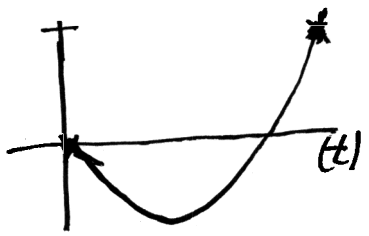
$\Delta y_2 = -137.6$; $h_2 = 137.6\ m$

$\Delta y_3 = v_3 \cdot t_3 = (-10)(60) = -600\ m \Rightarrow h_3 = 600$

$H = 600 + 137.6 + 176.4 = 914\ m$ (a) is correct

6. If the displacement of an object is given in SI units by $x(t) = -3t + 4t^2$, at $t = 2$ s its velocity and acceleration are, respectively

a. positive, positive
b. positive, negative
c. negative, negative
d. negative, positive
e. None of the above, because the signs change with time.



$x(t=0) = 0$
$x(t=1) = -3 + 4 = +1$
$x(t=2) = -6 + 4 \cdot 4 = +10$

Then at $t=2$ x is past its minimum and has a positive slope $\Rightarrow v(2) > 0$.
and it has an increasing slope $\Rightarrow a(2) > 0$
(a) Positive, Positive is correct

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7. Five boys are pushing on a snowball, and each is pushing with a force of 10.0 N. However, each boy is pushing in a different direction. They are pushing north, northeast, east, southeast, and south. (Each boy is pushing at an angle of 45.0° relative to his neighbor.) What is the magnitude of the total force on the ball?

a. 0
b. 17.1 N
c. 24.1 N
d. 27.1 N
e. 34.1 N

Vector form is $F^{NET} = F_1 + F_2 + F_3 + F_4 + F_5$

& y component is $F_y^{NET} = (+\cancel{10} + 10\cos 45° + 0 - \cancel{10\cos 45} - \cancel{10})$
$= 0$

& x Component is $F_x^{NET} = (0 + 10\cos 45° + 10 + 10\cos 45° + 0)$
$= 10 + \cancel{2}\cdot 10\cdot\frac{\sqrt{2}}{\cancel{2}} = 10 + 14.14$
$= \boxed{24.1\,N = |F^{NET}_{TOTAL}|}$

Forces are

(c) is correct answer

8. A helicopter is traveling at 40 m/s at a constant altitude of 100 m over a level field. If a wheel falls off the helicopter, with what speed will it hit the ground? (g = 9.8 m/s^2 and air resistance is negligible.)

a. 40 m/s
b. 50 m/s
c. 60 m/s
d. 70 m/s
e. 80 m/s

$\vec{v_0} = (v_{0x}, v_{0y}) = (40, 0)$

$v_x = v_{0x} + a_x t = 40 + 0 =$ constant, indep of time

$v_y = v_{0y} + a_y t = \cancel{v_{0y}}^{0} + gt =$

and wheel strikes ground at t_f

such that $\Delta y = \cancel{v_{0y}}^{0} + \frac{g}{2}t_f^2 = -H = y_i - y_f$

i.e. $t_f = \sqrt{-2H/g}$ $\quad g = -9.80\,m/sec^2$

Then $v_y(t_f) = -g t_f = \sqrt{-2gH}$ $\quad \sqrt{v_f^2} = |\vec{v_f}| = \sqrt{v_{0x}^2 - 2gH}$
$v_x(t_f) = v_{0x}$

$= \sqrt{(40)^2 + 2(9.80)100}$
$= \sqrt{1600 + 1960} = 59.7\,\frac{m}{sec.}$
$\approx 60\,m/sec$

(c) is correct

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9. A stone is thrown at an angle of 30° above the horizontal from the top edge of a cliff with an initial speed of 12 m/s. A stop watch measures the stone's trajectory time from top of cliff to bottom to be 5.6 s. Approximately how far out from the cliff's edge does the stone travel horizontally? (g = 9.8 m/s^2 and air resistance is negligible)

a. 30 m
b. 40 m
c. 50 m
d. 60 m
e. 70 m

At $t_f = 5.6$ sec

distance $= d = x(t_f) - x_0 = + v_{x0} t_f + \frac{1}{2} a_x t_f^2$, with $x_0 = 0$, $v_{x0} = v_0 \cos 30°$, $a_x = 0$

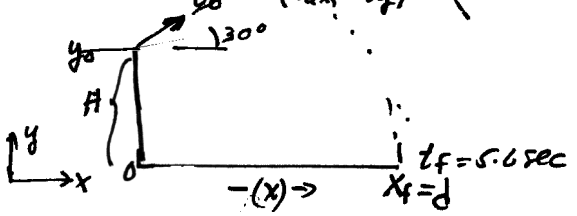
$= v_0 \cos 30° \cdot t_f$

$= 12 \cdot (0.866)(5.6)$

$= 58.20$ m. (d)

≈ 60 m.

$\vec{v}_0 = (v_{0x}, v_{0y}) = (|\vec{v}_0| \cos 30°, |\vec{v}_0| \sin 30°)$



10. A stone is thrown at an angle of 30° above the horizontal from the top edge of a cliff with an initial speed of 12 m/s. A stop watch measures the stone's trajectory time from top of cliff to bottom to be 5.6 s. What is the height of the cliff? (g = 9.8 m/s^2 and air resistance is negligible)

a) 70 m
b) 120 m
c) 170 m
d) 220 m
e) 270 m

Consider vertical motion; let top of cliff be at $y = y_0 = H$

$y(t) = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$

At $t = t_f$ stone strikes bottom, where $y(t_f) = 0$

Then $y(t_f) = 0 = y_0 + v_{0y} t_f + \frac{1}{2} g t_f^2$

$y_0 = -v_{0y} t_f + \frac{g}{2} t_f^2 = -|\vec{v}_0| \sin 30° t_f - \frac{g}{2} t_f^2$

$= -12 \cdot \frac{1}{2} \cdot (5.6) + \frac{9.80}{2}(5.6)^2 = -33.6 + 153.7$

Height $= y_0 = 120.$ m

& (b) is closest answer

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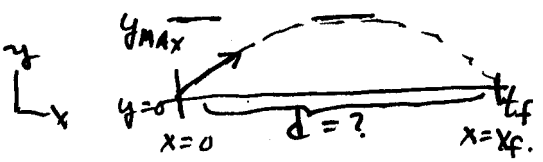
11. A ball is launched from ground level at 30 m/s at an angle of 35° above the horizontal. How far does it go before it is at ground level again, most nearly?

a. 15 m
b. 40 m
c. 65 m
d. 90 m
e. 115 m

$\vec{v}_0 = (v_{0x} = |\vec{v}_0|\cos 35°,\ v_{0y} = |\vec{v}_0|\sin 35°)$. (a)

$d = x_f = x(t_f) = x_0 + v_{0x} t_f$ (b) & we need t_f.

Use y motion (c) $v_y(t) = v_{0y} + gt = 0$ at t_1 where $y = y_{MAX}$



And $2t_1$ is time to rise to y_{MAX} & fall back to earth: $2t_1 = t_f$

Then $t_f = 2t_1 = 2(-v_{0y}/g) \Rightarrow d = v_{0x} \cdot 2\left(\frac{-v_{0y}}{g}\right)$

$= 30\cos 35° \cdot 2 \cdot \frac{30 \sin 35°}{(9.80)}$

$= (183.67)(0.8192)(0.5736)$

$= 86.3\,m$. (d) is best answer

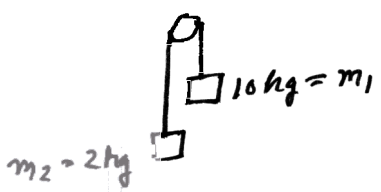
12. A 10–kg mass and a 2.0–kg mass are connected by a light string over a massless, frictionless pulley. If $g = 9.8\ m/s^2$, what is the acceleration of the system when released?

a. $4\ m/s^2$
b. $6\ m/s^2$
c. $8\ m/s^2$
d. $10\ m/s^2$
e. $12\ m/s^2$

Let y be positive when m_2 moves up & m_1 moves down: $g = |g| = 9.80$*

$F_{NET} = Ma = (m_1 + m_2)a = +m_1 g - m_2 g$ (A)

$a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g = \frac{8}{12}(9.80) = 6.53\ m/s^2$



* Take g positive & insert signs for forces explicitly in (A)

(b) is closest answer

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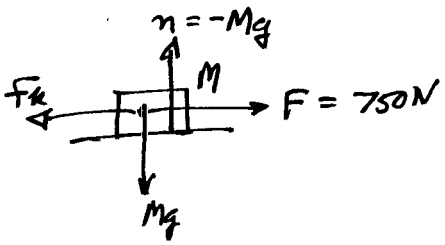
13. A horizontal force of 750 N is needed to overcome the force of static friction between a level floor and a 250–kg crate. What is the acceleration of the crate if the 750–N force is maintained after the crate begins to move and the coefficient of kinetic friction is 0.12?

a. 1.8 m/s^2
b. 2.5 m/s^2
c. 3.0 m/s^2
d. 3.8 m/s^2
e. 4.2 m/s^2



$|f_k| = \mu_k \cdot |\vec{n}| = (0.12)(250)(9.80) = 294\ N$

$F_{NET} = F - f = Ma \Rightarrow a = \frac{F - \mu_k M|g|}{M}$

$= \frac{750 - 294}{250} = \boxed{1.82\ \frac{m}{s^2}\ \text{(a)}}$

14 A 70.0kg man jumps 1.00 m down onto a concrete walkway. His downward motion stops in 0.0200 seconds. If he forgets to bend his knees, what average force is transmitted to his leg bones as he stops?

a. 15 000 N
b. 7 000 N
c. 5 000 N
d. 3 500 N
e. 2 000 N

$|F_{AVG}| = m\,|a_{AVG}| = m\left|\frac{\Delta v}{\Delta t}\right| = \frac{m\sqrt{2gd}}{\Delta t}$

Just before hitting concrete man's velocity is

$v_f = \sqrt{v_f^2} = 0^2 + \sqrt{2gd}$ just before hitting $= \Delta v$

d = 1m = distance of fall

← deceleration occurs in 0.02sec. = Δt

& v drops from v_f to 0

Then $|\vec{F}_{AVG}| = \frac{70\sqrt{2(9.80)1}}{2\times10^{-2}\,sec} = \boxed{15{,}495\ N\ \text{(a)}}$

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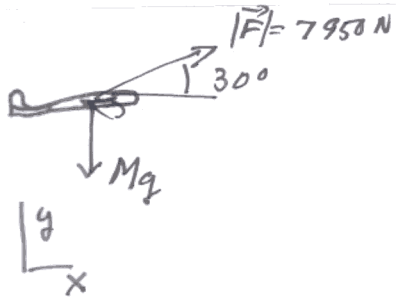
15. On takeoff, the combined action of the air around the engines and wings of an airplane exerts an 7950–N force on the plane, directed upward at an angle of 30 degrees above the horizontal. The plane rises with constant velocity in the vertical direction while continuing to accelerate in the horizontal direction. What is the mass of the plane, most nearly?

a) 300 kg
b) 400 kg
c) 500 kg
d) 600 kg
e) 700 kg



CONST Vertical Velocity $\Rightarrow a_y = 0 = F_y^{NET} = 0$

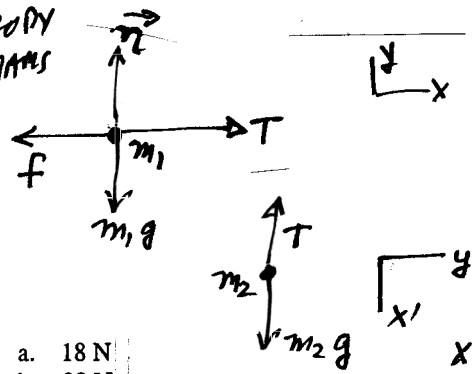
$F_y^{Net} = |\vec{F}| \sin 30° + Mg = 0$

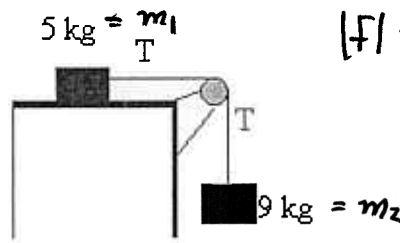
$\Rightarrow \quad M = -\frac{|\vec{F}| \sin 30°}{g} = \frac{+7950\,(0.500)}{+9.80}$

$= 405$ kg: (b) is best answer

16. A 9.0–kg hanging weight is connected by a string over a pulley to a 5.0–kg block sliding on a flat table. If the coefficient of sliding friction is 0.20, find the tension in the string.

FREE BODY DIAGRAMS





$|f| = \mu_k |\vec{n}| = \mu_k |m_1 g|$
$= 9.8$ N
$m_1 g = 49$ N

a. 18 N
b. 23 N
c. 28 N
d. 33 N
e. 38

x: $T - \mu_k |\vec{n}| = m_1 a_1 = m_1 a$ (A)

x': $-T + m_2 |g| = m_2 a_2 = m_2 a$ (B)

and $a_1 = a_2 = a$ if STRING IS TAUT

a & T are unknowns. to get T, eliminate (a)

(B): $-T/m_2 + g = a$ & insert into (A): $T - \mu_k |\vec{n}| = m_1 \left(\frac{-T}{m_2} + g\right)$

& solve for T: $T\left(1 + \frac{m_1}{m_2}\right) = \mu_k |\vec{n}| + m_1 |g|$

$T = \frac{9.8 + 49}{1 + 5/9} = 37.8$ N (e) is best answer

17 & 18. A 70.0 kg man stands on a spring scale in an elevator. Starting from rest, the elevator ascends, accelerating uniformly until attaining its maximum speed of 1.6 m/s in 0.40 s. It travels with this constant speed for 5.0 s, undergoes a uniform *negative* acceleration for 2.1 s, and comes to rest. (Recall that a spring scale measures the upward contact force the scale exerts on the man, the units for which are here taken to be Newtons, N.)

17 a.(3 points) What does the spring scale register before the elevator starts to move?

17b.(3 points) What does it register during the first ~~0.80~~ s? Error: should be 0.40 sec to correspond with text above.

18(a)(3 points) What does it register while the elevator is traveling at constant speed?

18(b)(3points) What does it register during the negative acceleration?

$\vec{F_S}$ is upward force on man by scale
Mg " gravitation " " " (downward $\Rightarrow g = -9.80\ m/sec^2$)

17(a) With elevator at rest, spring scale measures $\vec{n} = -M\vec{g}$, the contact force on the man's feet which keeps him from accelerating downward under gravity. i.e $|\vec{F_S}| = (70)(9.8) = \boxed{686\,N}$

17(b) For first ~~0.80s~~ 0.40 sec acceleration is positive (upward) at rate $a = \Delta v/\Delta t = 1.6/0.4 = 4\ m/sec^2$

Then $\vec{F}^{NET} = \vec{F}^S + M\vec{g} = m\vec{a} \Rightarrow F_S = -M\vec{g} + m\vec{a}$

& $|\vec{F_S}| = 686 + (70)4 = \boxed{966\,N}$

18(a) Constant speed $\Rightarrow \vec{a} = 0 \Rightarrow \vec{F}_{NET} = 0 = F_S + F_G$

Then $\vec{F_S} = -F_G = -m\vec{g} = -m(-9.80) = +\boxed{686\,N = F_S}$

18(b) For negative acceleration

$a' = \frac{-1.6\ m}{2.1\ sec^2} = -0.762\ m/s^2$

$F_G = m\vec{g} = -686\,N$

$ma' = -53.3\,N$

$m\vec{a}' = \vec{F_S} + \vec{F_G}$

$\vec{F_S} = m\vec{a}' - F_G = -53.3 - (-686) =$

$\boxed{F_S = 633\,N}$

19 & 20. A dockworker loading crates on a ship finds that 15–kg crate, initially at rest on a horizontal surface, requires an 80–N horizontal force to set it in motion. However, after the crate is in motion, a horizontal force of 54 N is required to keep it moving with a constant speed.

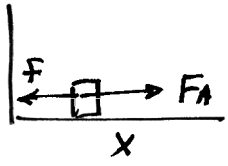
19.(6 points) calculate the coefficient of kinetic friction between the crate and the floor.

20.(6points) If a force of 150 N is applied to the crate directed at an angle of 45 degrees above the horizontal, how far does the crate move in **3** seconds, starting from rest?

19. $54N = F_A$ moves crate at constant speed $\Rightarrow$ zero acceleration

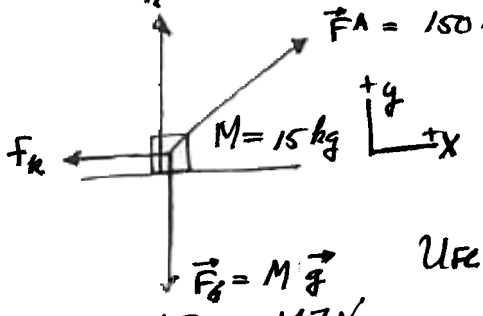
Then $\vec{F}_{NET} = m\vec{a} = 0 = \vec{F}_A + \vec{f}$ (where $\vec{f}$ opposes motion)

$|f| = |-54N| = 54N = \mu_k |\vec{n}| = \mu_k \cdot mg$, & $mg = (9.8)15 = 147N$



Then $\mu_k = \frac{|f|}{mg} = \frac{54N}{\ldots} = \boxed{0.37 = \mu_k}$

20



$|F_g| = 147N$

Forces acting on crate

$F^A_y = +|F^A| \sin 45° = 106.1 N$

$F^A_x = +|F^A| \cos 45° = 106.1 N$

NII: $\vec{F}_{NET} = m\vec{a}$

$F_{NET} = \vec{F}^A + \vec{n} + M\vec{g} + f_k$

$|f_k| = \mu_k |\vec{n}|$ and direction is opposite to $\vec{v}$

& we need $|\vec{n}|$ to calculate $|f_k|$

Use Y-Components $M a_y = F^A_y + Mg_y + n_y$

$= 0$ if $|F^A_y| < |Mg|$

$\Rightarrow n_y = -Mg_y - F^A_y = +M|g|$

$|\vec{n}_y| = M|g| - F^A_y = 147 - 106 = 41N$

Then X-components yield a_x:

$Ma_x = F^A_x - f_k = 106 - (0.37)41N = 91N$

$a_x = 91/15 = 6.1 \frac{N}{kg} = 6.1 \frac{m}{(sec)^2}$

& Distance travelled in time t seconds is $\boxed{D = \frac{1}{2}at^2 = \frac{1}{2}(6)(3^2) = 27m}$ for $t = 3$ sec.

END of Solutions