Massachusetts Institute of Technology
Department of Physics

Physics 8.01L

SAMPLE EXAM 2 SOLUTIONS November 1, 2005

Problem 1

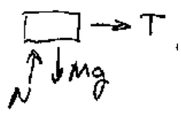
i) a) Object A Same force, smaller mass, so A has a bigger acceleration and moves the same distance in a shorter time.
ii) c) Both are the same. Same force, same distance, so the same change in kinetic energy.
iii) a) Object A. Smaller mass so smaller normal force, therefore smaller friction. Net force is larger on A, so it gains more kinetic energy.
iv) a) Object A. B moves up and stops completely. At its maximum height, A still has horizontal motion.
v) b) Objects B They start with the same kinetic energy (KE). B converts all of its KE to gravitation potential energy (PE), while A always has some non-zero KE.

Problem 2

A) iv) Same force by Newton's 3rd law.
B) iv) None of the above. $N_A - M_A g - F = -M_A a, \;\Rightarrow N_A = M_A g + F - M_A a$
C) iii) Less than $m_A g$ but not zero. $T - M_A g = -M_A a, \;\; T = M_A(g - a)$
D) iv) Normal force does work and creates PE. N points up, motion is up $\Rightarrow$ + Work KE is constant, but PE rises.

Problem 3

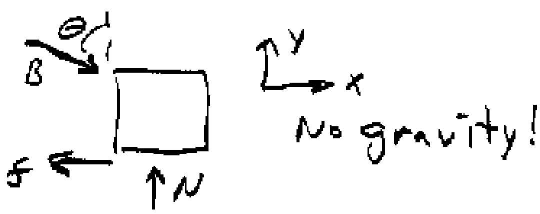
a)



$a = \frac{v^2}{R}, \;\; v = \frac{2\pi R}{\tau}$
b) $a = \frac{v^2}{R} = \frac{4\pi^2 R}{\tau^2}$ Spring is stretched a distance R so:
$T = kR = ma = m\left(\frac{4\pi^2}{\tau^2}\right) R$, R drops out.
$\tau = 2\pi\sqrt{\frac{m}{k}}$

Problem 4

a)



b) $\sum F_x = Bsin(\theta) - f = 0, \;\; f = Bsin(\theta)$
$\sum F_y = -Bcos(\theta) + N = 0, \;\; N = Bcos(\theta)$

c) B will not move if $f < \mu N, \;\; Bsin(\theta) < \mu Bcos(\theta)$
B drops out. Block <u>will</u> move if $sin(\theta) > \mu cos(\theta)$, or $tan(\theta) > \mu$

Problem 5

a) $y = H + vt - \frac{1}{2}gt^2, \;\; y = H$ at $vt - \frac{1}{2}gt^2 = 0, \;\; t = \frac{2v}{g}$.
b) $N = B$ by Newton's 3rd law.
c) $N = 0$ No contact.
d) $E_I = 0, \;\; E_F = m_g H + \frac{1}{2}mv^2, \;\; W = BH = E_F - E_I \Rightarrow B = m_g + \frac{mv^2}{2H}$

Problem 6

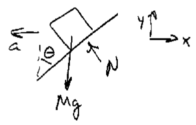
a) $F_x = Fcos(\theta) = \frac{2mg}{tan(\theta)}, \;\; a_x = \frac{2g}{tan(\theta)}$

$x = 100t + \frac{1}{2}a_x t^2 = 100(12) + \frac{1}{2}\frac{2g}{tan(\theta)}(12)^2 = 1200 + \frac{1440}{tan(\theta)}$
$\sum F_y = Fsin(\theta) - mg = 2mg - mg = mg, \;\; a_y = +g$
$y = 0 \cdot (12) + \frac{1}{2}g \cdot (12)^2 = 720.$

b) This problem uses a calculator, your exam will not require a calculator.
$v_x = 100 + \frac{2g}{tan(\theta)}(12) = 239 \; m/s.$
$v_y = g \cdot (12) = 120 \; m/s$
$v = \sqrt{v_x^2 + v_y^2} = 267 m/s$, at 26.7° above horizontal.

Problem 7

a)

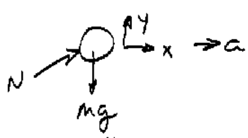


b) $\sum F_y = 0 - mg + Nsin(\theta) = 0, \;\; N = \frac{mg}{sin(\theta)}$

c) $\sum F_x = -Ncos(\theta) = -m\frac{v^2}{R}, \;\; R = Htan(\theta)$
Use answer to **(b)**: $\frac{mg}{sin(\theta)}cos(\theta) = \frac{mv^2}{Htan(\theta)}, \;\; v^2 = \sqrt{Hg}.$

Problem 8

a)



b) $\sum F_x = Nsin(\theta) = ma, \;\; \sum F_y = Ncos(\theta) - mg = 0.$
c) $N = \frac{mg}{cos(\theta)}, \;\; a = \frac{Nsin(\theta)}{m} = gtan(\theta).$

Problem 9

a) The suit case is sliding so it has kinetic friction. Belt is horizontal and no vertical forces other than gravity so $f = \mu_k mg$.

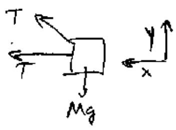
b) $a = \frac{F}{m} = \mu_k g, \;\; v = at = \mu_k gt = u \Rightarrow t = \frac{u}{\mu_k g}$.

c) No PE so $W = \Delta KE = \frac{1}{2}mu^2 - 0 \Rightarrow W_{frict} = \frac{1}{2}mu^2$.

d) At this point, the suit case moves at constant velocity, so $f = 0$.

Problem 10

a)



b) $\sum F_x = T + Tsin(\theta) = m\frac{v^2}{L}$
$\sum F_y = Tcos(\theta) - mg = 0$.

Problem 11. Young & Freedman 7.58 (pg. 278).

a) Call $h = 0$ the bottom end of the rod when it is vertical. Call the length of the rod L:
$KE_I = 0, \;\; KE_F = \frac{1}{2}m_{rat}v^2 + \frac{1}{2}m_{mouse}v^2$.
The rod pivots around the center so both animals move at the same speed.
$PE_I = g(m_{rat} + m_{mouse})\frac{L}{2}, \;\; PE_F = g(m_{rat} - m_{mouse})L$.
$W = 0$, since no forces other than gravity: $v^2 = \frac{(m_{rat} - m_{mouse})Lg}{m_{rat} + m_{mouse}}, \;\; v = 1.8m/s$.

Problem 12. Young & Freedman 7.61 (pg. 279).

a) Dropping a distance h, no friction: $\frac{1}{2}mv^2 = mgh, \; v^2 = 2gh$.
Dropping a distance d with friction, but gaining the same KE: $KE_I = 0, \; KE_F = mgh, \; PE_I = mgd$.
$PE_F = 0, W = -fd, \; W = \Delta E, \;\; -fd = mgh - mgd$
$f = mg\left(\frac{d-h}{d}\right)$. If $h = d, \; f = 0$, as expected.
If $h = 0$, no velocity! $f = mg$.

b) 440 Newtons.

c) $KE_I = 0, \; KE_F = \frac{1}{2}mv^2, \; PE_I = mgd, \; PE_F = mgy, \; W = -f(d-y)$
Using the value of f found in **a)**: $-f(d-y) = -mg\frac{(d-h)(d-y)}{d} = \frac{1}{2}mv^2 + mgy - mgd$
m drops out $\Rightarrow v^2 = 2g(d-y) - 2g\frac{(d-h)(d-y)}{d} = 2g\frac{(d-y)h}{d}, \;\; v = \sqrt{2g\frac{(d-y)h}{d}}$

Problem 13. Young & Freedman 7.65 (pg. 279).

a) $W = \Delta E, \;\; KE_I = \frac{1}{2}(m)(4.8)^2, \;\; KE_F = 0, \;\; W = -fd$
$f = \mu N$ and $N = mg$, so: $-\frac{1}{2}m(4.8)^2 = -\mu mgd, \;\; \mu = 0.39$

b) $W = \Delta E, \;\; PE_I = mg(1.6), \;\; PE_F = 0, \;\; KE_I = 0, \;\; KE_F = \frac{1}{2}m(4.8)^2$
$W = \Delta E = \frac{1}{2}m(4.8)^2 - mg(1.6) = -0.83\,J$