Spring 2018

Name, Surname:	Signature:
Exam Room: «Exam_Room»	Student ID Number: «ID»

Solutions

PHYS 102 General Physics I – Midterm 2

3 May, 2018 Thursday 19:00 -20:50

Please read!

- Count to make sure that there are 7 pages in the question booklet.
- Check your name and surname on front page, and student ID number on each page, and sign each page.
- This examination is conducted with closed books and notes.
- Put all your personal belongings underneath your seat and make sure that pages of books or notebooks are not open.
- Absolutely no talking or exchanging anything (like rulers, erasers) during the exam.
- You must show all your work to get credit; you will not be given any points unless you show the details of your work (this applies even if your final answer is correct!).
- Write neatly and clearly; unreadable answers will not be given any credit.
- If you need more writing space, use the backs of the question pages and put down the appropriate pointer marks.
- Make sure that you include units in your results.
- Make sure that you label the axis and have units in your plots.
- You are not allowed to use calculators during this exam.

P101_Index:

Short Questions

1	2	3	4	5	6	7	8	9	10

Problems

1	2	3	4

TOTAL

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1- SHORT QUESTIONS (3 points each)

1) The potential energy of a block of mass m = 0.2kg that is moving along the x-axis is given by $U(x) = 8x^2 - 2x^4$ in Joules. When the block is at the point x = 1m, what would be its acceleration (in m/s^2)?

a) -40 b) 40 c) -4 d) 4 e) 20

2) You are applying a constant force $\vec{F} = (-8.00N)\vec{i} + (3.00N)\vec{j}$ to a box that is sliding along the xy-plane. At the instant when the velocity of the box is $\vec{v} = (3.2m/s)\vec{i} + (2.20m/s)\vec{j}$ what is the instantaneous power supplied by this force (in Watts)?

a) 19 b) 32.2 c) -19 d) -32.2 e) None.

3) Two uniform spheres, both with mass M and radius R, are touching each other. The magnitude of their gravitational force of attraction will be

a) $\frac{4GM^2}{R^2}$ b) $\frac{GM^2}{R^2}$ c) $\frac{GM^2}{2R^2}$ d) $\frac{GM^2}{4R^2}$ e) None.

4) An earth satellite moves in a circular orbit with an orbital speed of6200m/s. What is the time it takes for one revolution of the satellite?

a) 54 minutes b) 81 minutes c) one and a half hour d) 108 minutes e) None

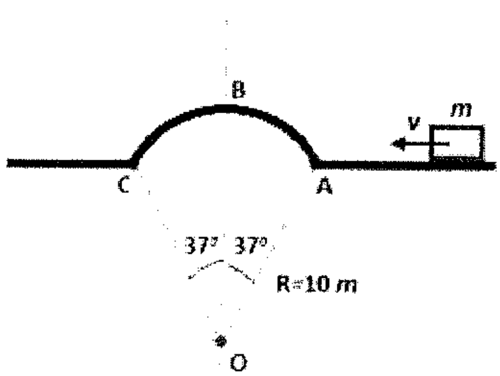
5) A body of unknown mass is attached to an ideal spring with force constant 128N/m.
If it is observed to oscillate with a frequency of 6.30Hz, then the mass of the body is

a) 40 grams b) 80 grams c) 100 grams d) 120 grams e) 160 grams

6) A small ball of mass 5g is shot vertically upwards by a spring gun. In order to hit a target that is 20m high, it is found that the spring must be compressed by 10cm. What is the value of the force constant of the spring (in Newtons/m)?

a) 197 b) 200 c) 201 d) 2000 e) 2010

7) A puck is moving on frictionless surface over a spherical elevation as shown in the figure. (Take $g = 10m/s^2$ for this problem.) If the speed of the puck at point A is 7m/s, then its speed at the highest point B will be



a) 9 b) 7.5 c) 6 d) 3 e) 1.5

Solution continues on the back side of the page **Yes** □ **No** □

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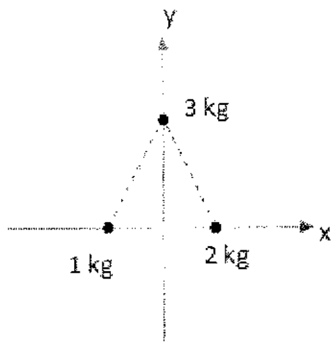
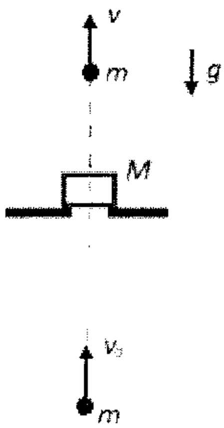
8) Three bodies with masses 1kg, 2kg, 3kg are put at the vertices of an equilateral triangle with a side equals 1meter as shown on the diagram. Where is the centre of mass of this 3-body system?



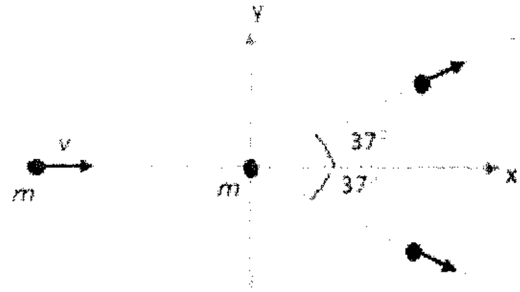
a) $\frac{1}{12}\vec{i}+\frac{\sqrt{3}}{4}\vec{j}$, b) $\frac{1}{6}\vec{i}+\frac{2}{\sqrt{3}}\vec{j}$, c) $\frac{1}{2\sqrt{3}}\vec{i}+\frac{1}{\sqrt{12}}\vec{j}$, d) $\sqrt{\frac{2}{3}}\vec{i}+\frac{1}{6}\vec{j}$, e) None.

9) A m = 20g bullet shot at the speed of v_0 = 600m/s hits and passes through a M = 1kg thin, wooden block that was initially at rest as shown on the diagram. If the bullet is observed to emerge from the block with a speed of v = 200m/s, then what will be the maximum height (in meters) that the block will rise vertically from its initial position? (Take g = 10m/s^2 for this problem too.)



a) 3.2 b) 2.8 c) 2.2 d) 1.9 e) 1.5

10) A body of mass m = 1kg moving at a speed of 8 m/s hits another body of the same mass that was at rest. They scatter as shown in the diagram. What is kinetic energy (in Joules) lost during the collision?



a) 0 b) 3 c) 5 d) 7 e) 9

Solution continues on the back side of the page Yes □ No □

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PROBLEMS (20 points each) Write all the relevant equations and show details of your calculations.

Problem 1 A minibus of mass m has a brake failure while going down a slippery road of constant downward slope angle α. Initially it was going downhill at speed v_0. After speeding up along the slope over a distance L with almost no friction, the driver was able to steer the minibus to a side onto a safety ramp with a constant upward slope angle β. The ramp has a rough surface for which the coefficient of rolling friction is μ_r.
What is the distance that the minibus moves along the safety ramp before it comes to a stop?

Solution continues on the back side of the page **Yes** □ **No** □

SOLUTION

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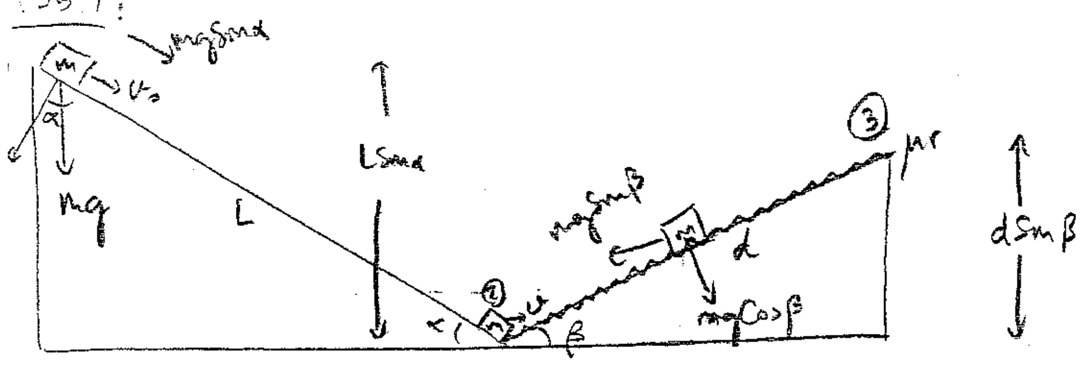
Prob. 1:



(1) It speeds up along the slope over a distance L.

$$ma = mg\,\mathrm{Sin}\,\alpha \Rightarrow a = g\,\mathrm{Sin}\,\alpha \Rightarrow v(t) = v_0 + (g\,\mathrm{Sin}\,\alpha)t$$

$$\Rightarrow x(t) = x_0 + v_0 t + \frac{g\,\mathrm{Sin}\,\alpha}{2} t^2$$

} don't do this, unnecessary.

Or using energy conservation $E_1 = E_2$

$$\frac{1}{2} m v_0^2 + mg L\,\mathrm{Sin}\,\alpha = \frac{1}{2} m v^2$$ (8)

(2) Over the ramp suppose the car goes a distance d.
Using energy conservation again $E_2 = E_3$

$$\frac{1}{2} m v^2 = mg\,d\,\mathrm{Sin}\,\beta + \underbrace{\mu_r \cdot mg\,\mathrm{Cos}\,\beta}_{F_f} \cdot \underbrace{d}_{\text{distance}}$$ (11)

↑ dissipation

Hence

$$\frac{1}{2} m v_0^2 + mg L\,\mathrm{Sin}\,\alpha = mg\,d\,\mathrm{Sin}\,\beta + \mu_r\, mg\,\mathrm{Cos}\,\beta\, d$$

$$d = \frac{\frac{v_0^2}{2} + gL\,\mathrm{Sin}\,\alpha}{g\,\mathrm{Sin}\,\beta + \mu_r g\,\mathrm{Cos}\,\beta}$$ (20)

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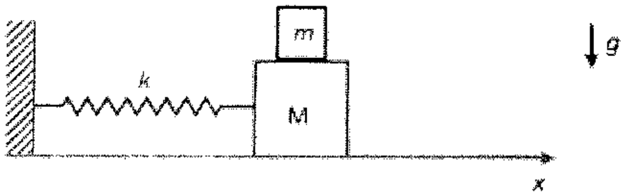
Problem 2 A block of mass M rests on a smooth horizontal surface. It is connected to a horizontal spring with force constant k whose other end is fixed to a wall. A second block of mass m rests on top of the first block. The coefficient of static friction between the blocks is μ_s.



(i) Determine the maximum amplitude of oscillation such that the top block will not slip on the bottom block?

(ii) Suppose the system is oscillating at an amplitude less than this maximum value. What is the period of oscillations?

Solution continues on the back side of the page **Yes** □ **No** □

Problem 2

i) A_{max} s.t top wont slip ?

(12)

$$\Sigma \vec{F} = m\vec{a}$$

for top mass $\Sigma \vec{F} = f_s = mg\mu_s$

$$mg\mu_s = ma$$

$$a = \mu_s g$$

max acc. at max Amplitud

system:

$$k A_{max} = (m + M) a$$

$$A_{max} = \frac{(M+m)\mu_s g}{K}$$

ii) $\omega = \sqrt{\frac{k}{m+M}}$ $T = \frac{2\pi}{\omega}$ (8)

⊗ Do <u>NOT</u> ask for extra credit

Just because you wrote $T = 2\pi\sqrt{\frac{m}{k}}$
or $a = \mu g$

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Problem 3 Suppose you are an astronaut exploring a distant planet. When your spaceship is in a circular orbit at a distance of 630km above the planet's surface, the ship's orbital speed is 4900m/s. By observing the planet, you estimate its radius to be $4.48\times10^{6}m$.

You then land on the surface and, at a place where the ground is level, launch a small projectile with initial speed 12.6m/s at an angle of 30^{0} above the horizontal.

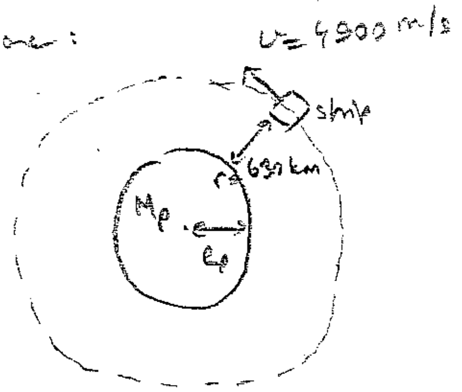
If the resistance due to the planet's atmosphere is negligible what is the maximum height the projectile will reach?

(Newton's universal gravitational constant $G = 6.67\times10^{-11}Nm^{2}/kg^{2}$)

[illegible] **Yes** ☐ **No** ☐

Prob 3:

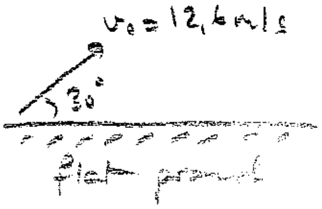
Suppose:



$R_p = 4,48 \times 10^6$

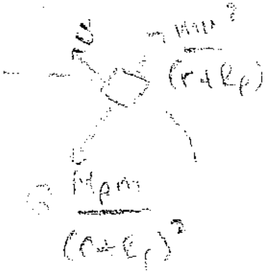
$M_p = ?$

Then we land and do:



$\downarrow g = ?$

First, need to find M_p by



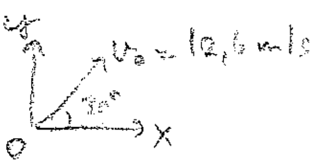
$$\Rightarrow \frac{mv^2}{(r+R_p)} = G\frac{M_p m}{(r+R_p)^2}$$

$$\Rightarrow M_p = \frac{v^2(r+R_p)}{G} \quad (5)$$

Then we find g_p by using $g_p = G\frac{M_p}{R_p^2} = \frac{v^2(r+R_p)}{R_p^2}$

$$g_p \simeq \frac{7^4 \times 10^{4} \times 5,11 \times 10^6}{4,48^2 \times 10^{12}} \simeq 611 \times 10^{-2} \simeq 6,11 \text{ m/s}^2 \quad (10)$$

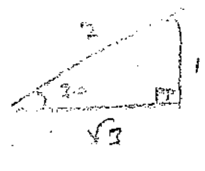
Now, the projectile experiment.



$\hat{x}$ dir: $x(t) = v_0 \cos 30 \cdot t$ (15)

$\hat{y}$ dir: $y(t) = v_0 \sin 30\, t - \frac{1}{2} g_p t^2$

and



The max height will be reached when $v_y(t) = v_0 \sin 30 - g_p t = 0$.

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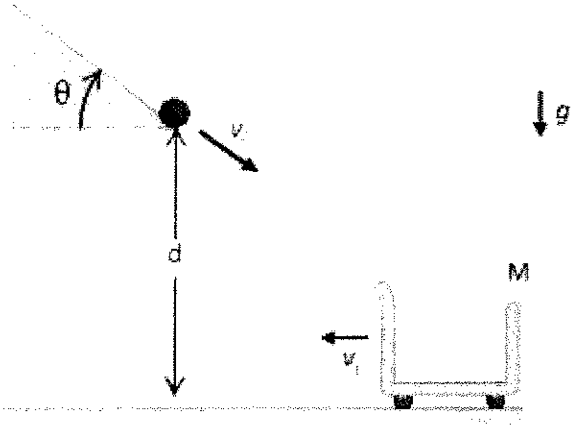
Problem 4 In a postal distribution center, an open cart of mass M = 45kg is rolling to the left along a smooth horizontal surface at a constant speed of v_i = 5.20m/s. A package of mass m = 15kg sliding down to the right on an inclined plane, that is inclined at $\theta = 30^0$ from the horizontal, shoots out with a speed of v_0 =2.60m/s. The lower end of the inclined plane is at a vertical distance of d=4.00m above the bottom of the cart. Suppose the package lands in the cart and they keep rolling together to the left.



(i) What will be the speed of the package just before it lands in the cart?

(ii) What will be the final speed of the cart moving with the package sitting inside?

Solution continues on the back side of the page **Yes** □ **No** □

Prob. 4

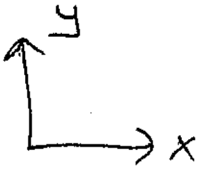
i) before collision (10)

$E_i = E_f$

$$\frac{1}{2} m V_0^2 + mgd = \frac{1}{2} m V_f^2$$

$$V_f = \sqrt{V_0^2 + 2gd} \simeq 9.22 \ m/s$$

ii) collision (10)



$$P_{x\,i} = P_{x\,f}$$

$$m \vec{V_x} + M \vec{V_{ix}} = (M+m) \vec{V_{fx}}$$

$$m V_0 . \cos\theta - M . V_i = (m+M) V.$$

$$V = \frac{m V_0 \cos\theta - M . V_i}{m + M} \simeq -3.33 \ m/s$$

⊗ Note only x comp of momentum is conserved.

$V_x = V_0 \cos\theta$ is constant throu motion of package