Solutions

Fall 2013
Physics 105, sections 1, 2 and 3
Exam 1
Colton

RED

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Please write your CID_____

No time limit. No notes. No books. Student calculators only. All problems equal weight, 60 points total.

Constants/Materials parameters:

$g = 9.8$ m/s^2
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
$k_B = 1.381 \times 10^{-23}$ J/K
$N_A = 6.022 \times 10^{23}$
$R = k_B \cdot N_A = 8.314$ J/mol·K
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4
Mass of Sun = 1.991×10^{30} kg
Mass of Earth = 5.98×10^{24} kg

Radius of Earth = 6.38×10^6 m
Radius of Earth's orbit = 1.496×10^{11} m
Density of water: 1000 kg/m^3
Density of air: 1.29 kg/m^3
Linear exp. coeff. of copper: 17×10^{-6} /°C
Linear exp. coeff. of steel: 11×10^{-6} /°C
Specific heat of water: 4186 J/kg·°C
Specific heat of ice: 2090 J/kg·°C

Specific heat of steam: 2010 J/kg·°C
Specific heat of alum.: 900 J/kg·°C
Latent heat of melting (water): 3.33×10^5 J/kg
Latent heat of boiling (water): 2.26×10^6 J/kg
Thermal conduct. of alum.: 238 J/s·m·°C
$v_{sound} = 343$ m/s at 20°C

Conversion factors

1 inch = 2.54 cm
1 mile = 1.609 km
1 m^3 = 1000 L

1 gallon = 3.785 L
1 atm = 1.013×10^5 Pa = 14.7 psi
$T_F = \frac{9}{5}T_C + 32$

$T_K = T_C + 273.15$

Other equations

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
Surface area of sphere = $4\pi r^2$
Volume of sphere = $(4/3)\pi r^3$
$v_{ave} = \frac{v_i + v_f}{2}$
$v = v_0 + at$
$x = x_0 + v_0 t + \frac{1}{2}at^2$
$v_f^2 = v_0^2 + 2a\Delta x$
$w = mg$, $PE_g = mgy$
$F = -kx$, $PE_s = \frac{1}{2}kx^2$
$f = \mu_k N$ (or $f \le \mu_s N$)
$P = F_{//}v = Fv\cos\theta$
$\vec{F}\Delta t = \Delta\vec{p}$
Elastic: $(v_1 - v_2)_{\text{bef}} = (v_2 - v_1)_{\text{after}}$
arc length: $s = r\theta$
$v = r\omega$
$a_{tan} = r\alpha$
$a_c = v^2/r$
$F_g = \frac{GMm}{r^2}$, $PE_g = -\frac{GMm}{r}$
$I_{pt\ mass} = mR^2$
$I_{sphere} = (2/5)\ mR^2$
$I_{hoop} = mR^2$

$I_{disk} = (1/2)\ mR^2$
I_{rod} (center) = $(1/12)\ mL^2$
I_{rod} (end) = $(1/3)\ mL^2$
$L = r_\perp p = rp_\perp = rp\sin\theta$
$P = P_0 + \rho gh$
$VFR = A_1 v_1 = A_2 v_2$
$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$
$\Delta L = \alpha L_0 \Delta T$
$\Delta V = \beta V_0 \Delta T$; $\beta = 3\alpha$
transl. $KE_{ave} = \frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_B T$
$Q = mc\Delta T$; $Q = mL$
$\frac{\Delta Q}{\Delta t} = kA\frac{T_2 - T_1}{L}$
$P = e\sigma AT^4$
$|W_{on\ gas}|$ = area under P-V curve
$= |P\Delta V|$ (constant pressure)
$= |nRT\ln(V_2/V_1)|$ (isothermal)
$= |\Delta U|$ (adiabatic)
$U = \frac{3}{2}Nk_B T = \frac{3}{2}nRT$ (monatomic)

$U = \frac{5}{2}Nk_B T = \frac{5}{2}nRT$ (diatomic, around 300K)
$Q_h = |W_{net}| + Q_c$
$e = \frac{|W_{net}|}{Q_{added}} = 1 - \frac{Q_c}{Q_h}$
$e_{max} = 1 - \frac{T_c}{T_h}$
$\omega = \sqrt{\frac{k}{m}}$, $T = 2\pi\sqrt{\frac{m}{k}}$
$\omega = \sqrt{\frac{g}{L}}$, $T = 2\pi\sqrt{\frac{L}{g}}$
$v = \sqrt{\frac{T}{\mu}}$, $\mu = m/L$
$\beta = 10\log\left(\frac{I}{I_0}\right)$ $I_0 = 10^{-12}$ W/m^2
$f' = f\frac{v \pm v_0}{v \pm v_S}$
$\sin\theta = v/v_s$
o-o/c-c: $f_n = nf_1$; $n = 1,2,3,\ldots$
o-c: $f_n = nf_1$; $n = 1,3,5,\ldots$

Instructions:

- Write your CID at the top of the first page, otherwise you will not get this exam booklet back.
- Circle your answers in this booklet if you wish, but be sure to **record your answers on the bubble sheet.**
- Unless otherwise specified, **ignore air resistance** in all problems.
- Use g = 9.8 m/s^2.

1. In many European countries, fuel economy is given in terms of "liters per 100 km" as opposed to the U.S. standard of "miles per gallon". If a given vehicle is rated at 6.5 liters per 100 km, what is its equivalent mpg rating? (Hint: there are some unit conversion factors on page 1 of the exam.)
    - a. 20-22 mpg
    - b. 22-24
    - c. 24-26
    - d. 26-28
    - e. 28-30
    - f. 30-32
    - g. 32-34
    - h. 34-36
    - [✓ i. 36-38]
    - j. 38-40 mpg

$$\frac{100\,\cancel{km}}{6.5\,\cancel{L}} \times \frac{1\ mi}{1.609\,\cancel{km}} \times \frac{3.785\,\cancel{L}}{1\ gallon} = \boxed{36.19\ \frac{mi}{gallon}}$$

2. Mia throws a ball straight upwards. While the ball is rising, in which direction is it accelerating?
    - a. Up
    - [✓ b. Down]
    - c. Not accelerating

3. Same situation. While the ball is falling, in which direction is it accelerating?
    - a. Up
    - [✓ b. Down]
    - c. Not accelerating

4. Same situation. While the ball is right at the top of its path, in which direction is it accelerating?
    - a. Up
    - [✓ b. Down]
    - c. Not accelerating

Freefall: always accelerating down due to gravity

5. George drives in a straight line, first for 100 s at 10 m/s, then for 100 s at 20 m/s. What was his average velocity?
    - a. 12 m/s
    - b. 13.33
    - [✓ c. 15]
    - d. 16.67
    - e. 18 m/s
    - f. Not enough information to determine.

① 100 s @ 10 m/s = 1000 m

② 100 s @ 20 m/s = 2000 m

$$V_{ave} = \frac{\Delta x}{\Delta t} = \frac{3000\,m}{200\,s} = \boxed{15\ m/s}$$

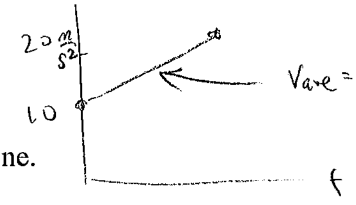
6. Fritz drives in a straight line, first for 1000 m at 10 m/s, then for 1000 m at 20 m/s. What was his average velocity?
    - a. 12 m/s
    - [✓ b. 13.33]
    - c. 15
    - d. 16.67
    - e. 18 m/s
    - f. Not enough information to determine.

① 1000 m @ 10 m/s = 100 s

② 1000 m @ 20 m/s = 50 s

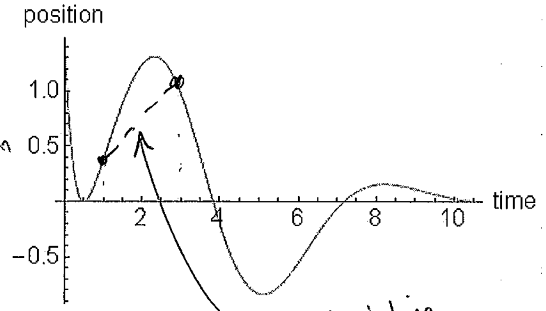
$$V_{ave} = \frac{\Delta x}{\Delta t} = \frac{2000\,m}{150\,s} = \boxed{13.33\ m/s}$$

7. Susan drives in a straight line, accelerating constantly from 10 m/s to 20 m/s. What was her average velocity?
    - a. 12 m/s
    - b. 13.33
    - [✓ c. 15]
    - d. 16.67
    - e. 18 m/s
    - f. Not enough information to determine.



Vave = midpt (since const. accel)

8. The graph on the right is a *position* vs. time graph for a car that is moving left and/or right (right = positive). How many times does the car stop and turn around?
   - a. 0
   - b. 1
   - c. 2
   - d. 3
   - [✓ e.] 4 (when slope changes between + and −)
   - f. 5
   - g. 6
   - h. 7



9. Same situation. What is the car's *average velocity* between 1 and 3 seconds? (Be care in reading values off the graph.)
   - a. 0.05 – 0.15 m/s
   - b. 0.15 – 0.25
   - [✓ c.] 0.25 – 0.35
   - d. 0.35 – 0.45
   - e. 0.45 – 0.55
   - f. 0.55 – 0.65
   - g. 0.65 – 0.75
   - h. 0.75 – 0.85
   - i. 0.85 – 0.95
   - j. More than 0.95 m/s

slope of that line $= \frac{\text{rise}}{\text{run}} = \frac{(1.05 - .4)\text{m}}{2\text{s}}$ by my best estimate

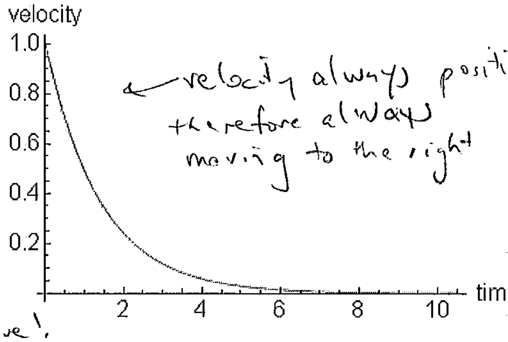
$= \boxed{.32 \text{ m/s}}$

(Exact number turns out to be $0.300 \frac{\text{m}}{\text{s}}$)

10. Same situation. At $t = 8$ s, what is the car's *acceleration*?
    - a. Positive
    - [✓ b.] Negative
    - c. Zero

slope is changing from a small positive value, to zero, which is a negative change

11. The graph on the right is a *velocity* vs. time graph for a car that is moving left and/or right (right = positive). Which of the following best describes its motion?
    - a. The car first moves to the right, and then moves to the left. No, always to right
    - b. The car has a constant negative acceleration. No – always negative, but not constant (slope is changing)
    - c. The car starts to the right of the origin, then it returns to the origin and stops. No, that would involve leftward motion and the velocity is always positive
    - [✓ d.] The car, initially moving to the right, slows down and stops. True!
    - e. More than one of the above.



← velocity always positive, therefore always moving to the right

12. Suppose my car's specs say it can stop from 60 mph (26.82 m/s) in 130 feet (39.62 m). If the acceleration during that time is constant, how many negative g's of acceleration do I experience?
    - a. 0.5 - 0.6 g
    - b. 0.6 – 0.7
    - c. 0.7 – 0.8
    - d. 0.8 – 0.9
    - [✓ e.] 0.9 – 1.0
    - f. 1.0 – 1.1
    - g. 1.1 – 1.2 g

$$v_f^2 = v_o^2 + 2a\Delta x$$

$$0 = (26.82 \tfrac{\text{m}}{\text{s}})^2 + 2a\,(39.62\text{m})$$

$$\boxed{a = -9.078 \tfrac{\text{m}}{\text{s}^2}} \times \frac{1\text{g}}{9.8 \frac{\text{m}}{\text{s}^2}} = \boxed{.926 \text{ g's}}$$

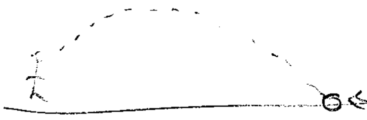
13. Suppose my car's specs say it can accelerate from 0 to 60 mph (26.82 m/s) with a constant acceleration of 1 g. How long will that take?
    - [✓ a.] 2.5 – 3.0 s
    - b. 3.0 – 3.5
    - c. 3.5 – 4.0
    - d. 4.0 – 4.5
    - e. 4.5 – 5.0
    - f. 5.0 – 5.5
    - g. 5.5 – 6.0
    - h. 6.0 – 6.5
    - i. 6.5 – 7.0 s

$$v = v_o + at$$

$$26.82 \tfrac{\text{m}}{\text{s}} = 0 + (9.8 \tfrac{\text{m}}{\text{s}^2})\,t$$

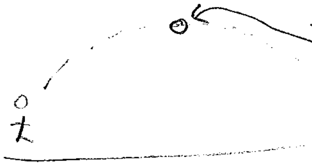
$$\boxed{t = 2.737\text{s}}$$

14. A boy throws a ball at an upward angle across a flat field. The ball leaves his hand 2 meters above the ground, and it lands on the field some distance away. At what part of its path does the ball have its *maximum* speed?
   - a. Right after it leaves his hand
   - b. Halfway to the top
   - c. At the top of its path
   - d. Halfway from the top to the ground
   - [✓ e.] Right before it hits the ground
   - f. There's not enough information to say



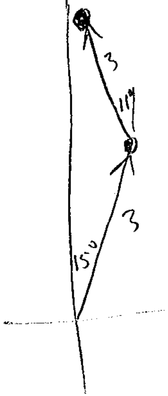
V_x = constant
V_y = largest } there

15. Same situation. At what part of its path does the ball have its *minimum* speed?
   - a. Right after it leaves his hand
   - b. Halfway to the top
   - [✓ c.] At the top of its path
   - d. Halfway from the top to the ground
   - e. Right before it hits the ground
   - f. There's not enough information to say



V_x = constant
V_y = smallest } there

16. A hiker wants to travel 6 miles due north, but unfortunately gets her bearings wrong. For the first 3 miles she travels 15° east of north; for the second 3 miles she travels 11° west of north. How close is she to where she wanted to be?
   - a. Less than 0.14 miles
   - b. 0.14 – 0.16
   - c. 0.16 – 0.18
   - d. 0.18 – 0.20
   - e. 0.20 – 0.22
   - f. 0.22 – 0.24
   - [✓ g.] 0.24 – 0.26
   - h. 0.26 – 0.28
   - i. More than 0.28 miles



use table to add components

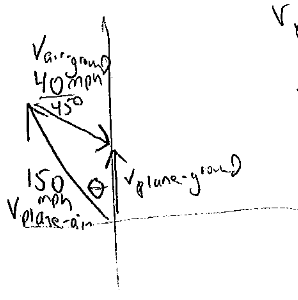
	x	y
vector1	3 sin 15°	3 cos 15°
vector2	−3 sin 11°	3 cos 11°
sum	.2040	5.8427

→ distance from (0,6) is

$d = \sqrt{(.2040)^2 + (6 - 5.8427)^2}$

$= \boxed{.2577 \text{ mi}}$

17. The pilot of an airplane wishes to fly due north in a 40 km/h wind blowing due south-east. The airspeed of the airplane (i.e. $\vec{v}_{\text{plane-air}}$) is 150 km/h. In what direction should the aircraft head? Specify how for west of north the angle must be.
   - a. Less than 8 degrees
   - [✓ b.] 8 – 11
   - c. 11 – 14
   - d. 14 – 17
   - e. 17 – 20
   - f. 20 – 23
   - g. 23 – 26
   - h. More than 26 degrees



$\vec{V}_{plane-ground} = \vec{V}_{plane-air} + V_{air-ground}$ vector velocity addition

From picture, x-components must cancel out.

$150 \sin\theta = 40 \cos 45°$

$\sin\theta = \frac{40 \cos 45°}{150}$

$\theta = \sin^{-1}\left(\frac{40 \cos 45°}{150}\right) = \boxed{10.87°}$

18. Same situation. What speed relative to the ground will the airplane be going?
   - a. Less than 86 km/h
   - b. 86 – 92
   - c. 92 – 98
   - d. 98 – 104
   - e. 104 – 110
   - f. 110 – 116
   - [✓ g.] 116 – 122
   - h. More than 122 km/hr

From picture, $\vec{V}_{plane-ground}$ = vector sum of y-components

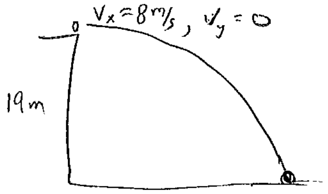
$V = 150 \cos(10.87°) - 40 \sin 45°$

$= \boxed{119.0 \text{ mph}}$

19. In one of the demos done in class, a ball was shot out horizontally at the same time that another ball was dropped from the same height with no horizontal velocity. Which ball hit the ground first?
   a. The one shot horizontally
   b. The one dropped
   [✓ c.] Same time

time governed by y-motion, which is the same.

20. Jane stands at the edge of a cliff and throws a stone horizontally over the edge with a speed of $v_x = 8$ m/s (the initial $v_y = 0$). The cliff is 19 m above a flat, horizontal beach. (I.e. use 19 m as the initial height of the stone.) How fast is the stone traveling when it hits the beach?
   a. Less than 18 m/s
   b. 18 – 19
   c. 19 – 20
   [✓ d.] 20 – 21
   e. 21 – 22
   f. 22 – 23
   g. More than 23 m/s



$V_x = 8 m/s$ still

Need v_y:

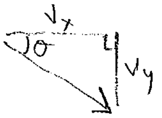
$v_y^2 = v_{oy}^2 + 2a\Delta y$

$v_y = \sqrt{0 + 2(-9.8 \frac{m}{s^2})(-19 m)} = 19.298 \frac{m}{s}$

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{8^2 + 19.298^2}$

$= \boxed{20.89 m/s}$

21. Same situation. With what angle does it land? (measured as an angle below horizontal)
   a. Less than 61 degrees
   b. 61 – 63
   c. 63 – 65
   d. 65 – 67
   [✓ e.] 67 – 69
   f. 69 – 71
   g. More than 71 degrees

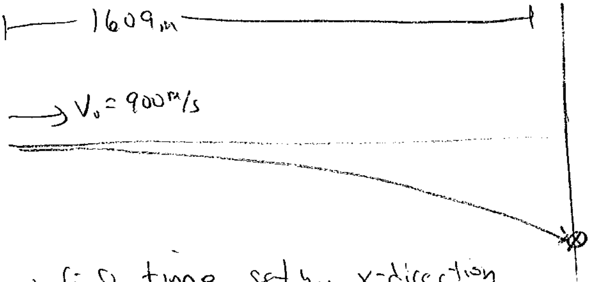


$\tan\theta = V_y/V_x$

$\theta = \tan^{-1}\left(\frac{19.298 \, m/s}{8 \, \cancel{m/s}}\right)$

$= \boxed{67.48°}$

22. Two months ago on the reality show Top Shot, contestants had to use a high powered rifle to hit a target one mile away (1609 m). The bullet they used has a typical muzzle velocity of 900 m/s, meaning that's the velocity with which it leaves the gun. For this problem let's assume the target was at the same elevation as the shooters. Also, let's assume that we can neglect wind and air resistance, although undoubtedly those would play large roles here. If a shooter aimed the barrel perfectly horizontally, directly at the center of the target, how much below the center would he or she hit? (assuming the bullet could fall that far without hitting the ground)
   a. Less than 12.0 m
   b. 12.0 – 12.5
   c. 12.5 – 13.0
   d. 13.0 – 13.5
   e. 13.5 – 14.0
   f. 14.0 – 14.5
   g. 14.5 – 15.0
   h. 15.0 – 15.5
   [✓ i.] More than 15.5 m



First find time, set by x-direction

$x = \cancel{x_0} + v_{ox}t$

$t = \frac{x}{v_{ox}}$

$t = \frac{1609 m}{900 s}$

$t = 1.788 s$

Now find distance it "falls", based on that time

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

$y = -\frac{1}{2}(9.8 \frac{m}{s^2})(1.788 s)^2$

$\boxed{y = -15.66 m}$