SOLUTIONS

EXAM 2

PHYSICS 1310

MARCH 5, 2022

80 POINTS + 10 POINTS OF EXTRA CREDIT POSSIBLE

CIRCLE ANSWER OR ANSWERS TO EACH QUESTION AS REQUIRED

UNLESS NOTED OTHERWISE IN PROBLEM DESCRIPTION, NO CREDIT WILL BE GIVEN WITHOUT AN APPROPRIATE EXPLANATION (TEXT AND/OR EQUATIONS) SUPPORTING EACH CORRECT ANSWER

PARTIAL CREDIT POSSIBLE FOR WORK SHOWN

3" X 5" CRIB SHEET OK, NO OTHER NOTES ETC. ALLOWED

NO ELECTRONIC DEVICES OF ANY KIND ALLOWED OR VISIBLE

USE BACK OF PAGE IF ADDITIONAL SPACE IS REQUIRED

1. (10 Points) What are the SI units of "torque"? - there may be more than one correct answer. (NO NEED TO SHOW ANY WORK)

A. Newtons

(B) Newton · meters

(C) $kg \cdot m^2/s^2$

D. $kg \cdot m/s^2$

E. $kg \cdot m/s$

F. $kg \cdot m^2/s$

(G) meter · Newtons

2. (10 Points) What are the SI units of "angular momentum"? - there may be more than one correct answer. (NO NEED TO SHOW ANY WORK)

A. Newtons

B. Newton · meters

C. $kg \cdot m^2/s^2$

D. $kg \cdot m/s^2$

E. $kg \cdot m/s$

(F) $kg \cdot m^2/s$

G. Joules

3. (10 Points). Write down Newton's law of universal gravitation for two masses, m_1 and m_2, separated by a distance r. Define (at least in words) any constants you include.

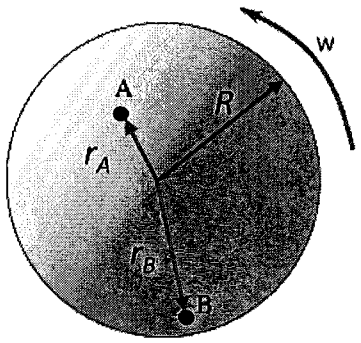
$$F = \frac{Gm_1m_2}{r^2}$$

G IS THE GRAVITATIONAL CONSTANT

ALTERNATIVELY YOU COULD WRITE THE VECTOR EQ. AS WE DID IN CLASS

$$\vec{F}_{12} = -\frac{Gm_1m_2}{r_{21}^2}\hat{r}_{21} \quad (\text{FORCE ON } m_1 \text{ BY } m_2)$$

4. (10 Points) A merry-go-round is rotating at constant angular speed as shown in the Figure. Consider two points on the merry-go-round, one at A and one at point B, where $r_B > r_A$



4.1. (2 Points) Which point, if either, has the greater angular velocity? Justify your answer.

THE ANGULAR VELOCITY $= \omega$ WHICH IS THE SAME FOR BOTH POINT A AND B

4.2. (2 Points) Which point, if either, has the greater magnitude of tangential acceleration? Justify your answer.

THE $|\text{TANGENTIAL ACCELERATION}| = \frac{dv}{dt} = r\frac{d\omega}{dt} = 0$ BECAUSE ω = CONSTANT, SO BOTH POINT A & B HAVE THE SAME |TANGENTIAL ACCELERATION| OF ZERO

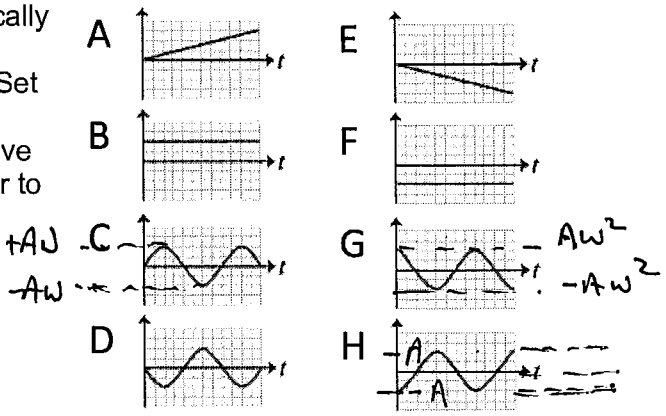
4.3. (3 Points) Which point, if either, has the greater magnitude of centripetal acceleration? Justify your answer.

THE $|\text{CENTRIPETAL ACCELERATION}| = \omega^2 r$ SINCE $r_B > r_A$, POINT B HAS THE GREATER CENTRIPETAL ACCELERATION

4.4. (3 Points) Which point, if either, has the greater magnitude of angular acceleration? Justify your answer.

THE $|\text{ANGULAR ACCELERATION}| = \frac{d\omega}{dt} = 0$ SO BOTH POINTS A & B HAVE THE SAME |ANGULAR ACCELERATION| $= 0$

5. (10 Points) An object of mass *m* is attached to a vertically oriented spring. The object is pulled a short distance below its equilibrium position and released from rest. Set the origin of the coordinate system at the equilibrium position of the object and choose upward as the positive direction. Assume air resistance can be ignored. Refer to the graphs on the right when answering the following questions.



SHORT DISTANCE => SIMPLE HARMONIC MOTION SINCE THEN F ∝ DISPLACEMENT

5.1. (3 Points) Beginning the instant the object is released, which graph best matches the position vs. time of the object. Justify your answer with an equation or equations and/or written discussion.

(H) SIMPLE HARMONIC MOTION DESCRIBED BY $\sin(\omega t+\varphi)$. FOR $t=0$ MASS WAS BELOW ITS EQUILIBRIUM POSITION AT A DISTANCE = THE AMPLITUDE OF THE MOTION. SO $y(t) \propto -\cos\omega t$

$= -A\cos\omega t$

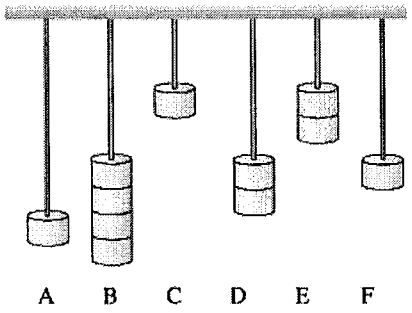
5.2. (3 Points) Beginning the instant the object is released, which graph best matches the velocity vs. time of the object. Justify your answer with an equation or equations and/or written discussion.

(C) $V = \frac{dy(t)}{dt} = +A\omega \sin\omega t$

5.3. (4 Points) Beginning the instant the object is released, which graph best matches the acceleration vs. time of the object. Justify your answer with an equation or equations and/or written discussion.

(G) $a = \frac{dV}{dt} = A\omega^2 \cos\omega t$

6. (10 Points) A combination of art and musical instrument is illustrated in the figure to the right. Six pieces of identical piano wire (cut to different lengths) are hung from the same support, and masses are hung from the free end of each wire. Each wire is 1, 2, or 3 units long, and each supports 1, 2, or 4 units of mass. The mass of each wire is negligible compared to the total mass hanging from it. When a strong breeze blows, the wires vibrate and create an eerie sound.



6.1. (3 Points) Rank each wire-mass system on the basis of its fundamental wavelength. Rank from largest to smallest. To rank items as equivalent, write their letters in a vertical column. Justify your answer.

LARGEST ⇒ SMALLEST

A | B D F | C E

$\lambda_{FUNDAMENTAL} = 2L$

6.2. (3 Points) Rank each wire-mass system on the basis wave speed. Rank from largest to smallest. To rank items as equivalent, write their letters in a vertical column. Justify your answer.

LARGEST ⇒ SMALLEST

B | D E | A C F

$WAVESPEED \propto T^{1/2}$

$T^{1/2} \propto MASS$

$= (mg)^{1/2}$

6.3. (4 Points) Rank each wire-mass system on the basis of its fundamental frequency. Rank from largest to smallest. To rank items as equivalent, write their letters in a vertical column. Justify your answer.

LARGEST ⇒ SMALLEST

E | B C | D | F | A

$f \propto \frac{V}{\lambda} \propto \frac{MASS^{1/2}}{L}$

$f_A \propto \frac{\sqrt{1}}{3} = \frac{1}{3} = 0.3$

$f_B \propto \frac{\sqrt{4}}{2} = 1$ ✓

$f_C \propto \frac{\sqrt{1}}{1} = 1$ ✓

$f_D \propto \frac{\sqrt{2}}{2} = 0.7$ ✓

$f_E \propto \frac{\sqrt{2}}{1} = 1.4$ ✓

$f_F \propto \frac{\sqrt{1}}{2} = \frac{1}{2} = 0.5$

7. (10 Points) An object is placed in a fluid and then released. Assume that the object either floats to the surface (settling so that the object is partly above and partly below the fluid surface) or sinks to the bottom. (Note that for Parts 1 through 3, you should assume that the object has settled to equilibrium.)

7.1. (5 Points) An object is floating in equilibrium on the surface of a liquid. The object is then removed and placed in another container, filled with a denser liquid. What would you observe? Justify your answer with equations and/or a sentence or two explanation.

A. The object would float submerged more deeply than in the first container.
B. The object would float submerged less deeply than in the first container.
C. The object would sink all the way to the bottom.
D. More than one of these outcomes is possible.

SINCE IN BOTH CONTAINERS THE OBJECT FLOATS

CONTAINER 1: $F_{BUOYANT} = \rho_1 g V_{SUB_1} =$ OBJECT WEIGHT

CONTAINER 2: $F_{BUOYANT} = \rho_2 g V_{SUB_2} =$ OBJECT WEIGHT

SO $\frac{\rho_1 V_{SUB_1}}{\rho_2 V_{SUB_2}} = 1$ $\quad \rho_2 > \rho_1 \Rightarrow V_{SUB_1} > V_{SUB_2}$

7.2. (5 Points) Two objects, *T* and *B*, have identical size and shape and have uniform density. They are carefully placed in a container filled with a liquid. Both objects float in equilibrium. Less of object *T* is submerged than of object *B*, which floats, fully submerged, closer to the bottom of the container. Which of the following statements is true? Justify your answer with equations and/or a sentence or two explanation.

A. Both objects have the same density.
B. Object *B* has a greater density than object *T*.
C. Object *T* has a greater density than object *B*.

SINCE B FLOATS SUBMERGED

$F_{BUOYANT\ ON\ B} = \rho_{FLUID} g V = \rho_B g V$

$\Rightarrow \rho_B = \rho_{FLUID}$.

SINCE T IS NOT COMPLETELY SUBMERGED

$\rho_T < \rho_{FLUID} \Rightarrow \rho_T < \rho_B$

8. (10 Points) Three identical point masses each of mass m are placed on the x-axis. One mass is at the origin, one is on the negative x-axis at x_1, and one on the positive x-axis at x_2. What is the net gravitational force, $\boldsymbol{F}$, on the mass at the origin due to the other two masses?

A. $Gm^2\,(1/(x_2^2 - x_1^2))\,\hat{i}$

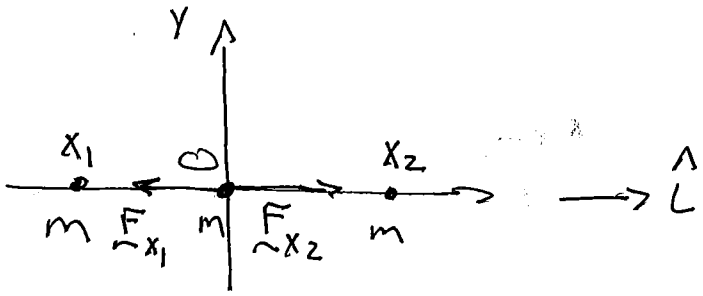
B. $Gm^2/(x_2 x_1)\,\hat{i}$

C. $Gm\,(1/x_2 - 1/x_1)\,\hat{i}$

D. $Gm^2\,(1/x_2 + 1/x_1)\,\hat{i}$

E. $Gm^2\,(1/x_1^2 - 1/x_2^2)\,\hat{i}$

F. $Gm^2\,(1/x_2^2 - 1/x_1^2)\,\hat{i}$

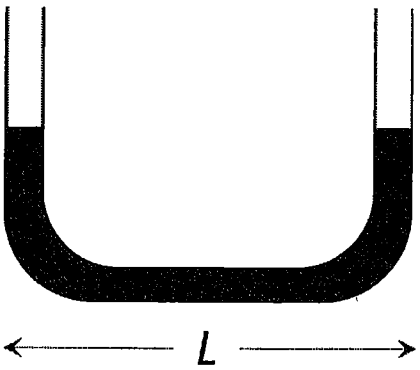


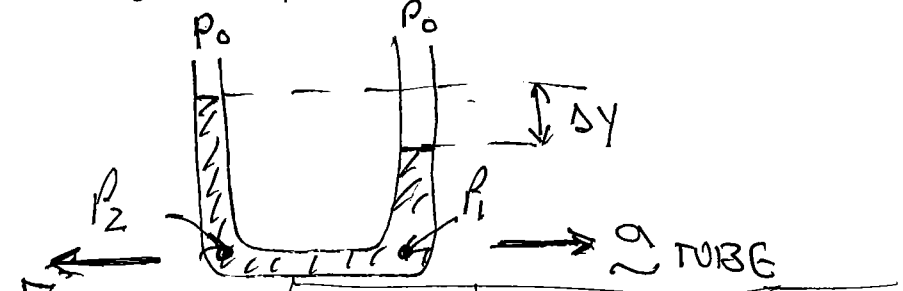
$$\underset{\sim}{F}_{NET} = \underset{\sim}{F}_{X_1} + \underset{\sim}{F}_{X_2}$$

$$= -\frac{Gmm}{X_1^2}\hat{L} + \frac{Gmm}{X_2^2}\hat{L}$$

$$= Gm^2\left(\frac{1}{X_2^2} - \frac{1}{X_1^2}\right)\hat{L}$$

EXTRA CREDIT (10 Points All or Nothing)
A U-tube of length L containing a liquid moves to the right with an acceleration a. What is the resulting difference in the height of the liquid in the vertical arms.





PASCALS LAW

$$\rho g \Delta Y = P_2 - P_1 = \Delta P = \rho g \Delta Y_{=m}$$

$$\Rightarrow \rho g \Delta Y = \Delta P = F_{FLUID}/A_{TUBE} = (\rho V)a/A_{TUBE} = \rho a (V/A_{TUBE})$$

VOLUME OF FLUID IN HORIZONTAL SECTION $= A_{TUBE} \cdot L$

$$\rho g \Delta Y = \rho a L$$

$$\Rightarrow \Delta Y = \frac{aL}{g}$$