PHYSICS 125 | THIRD EXAM | November 21, 1996

1. NAME:

VERSION 2 SOLUTIONS

FIRST: ______________________ LAST: ______________________

2. Circle your recitation instructor and section.

INSTRUCTOR		SEC.	INSTRUCTOR		SEC.
Schubnell	(8 AM)	3	Campbell	(9 AM)	12
Schubnell	(9 AM)	4	Campbell	(10 AM)	13
Campbell	(11 AM)	5	Dershem	(12 PM)	14
Rasul	(2 PM)	6	Dershem	(1 PM)	15
Rasul	(3 PM)	7	Dershem	(2 PM)	16
Rasul	(4 PM)	8	Schubnell	(3 PM)	17
Rasul	(4 PM)	10			

3. There are five questions, with the points indicated adding to 100 points.

- Questions one, two, and three are multiple choice, and no partial credit will be assigned. On these questions, choose the answer closest to the correct answer. You must **CIRCLE** the correct answer to get credit for the problem.
- Partial credit will be assigned on questions four and five. There will be **NO CREDIT** given on these problems for a correct answer without the corresponding work.

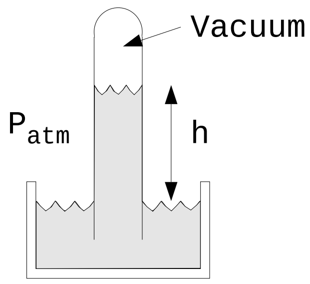
4. The exam is closed book. You may use one 3" x 5" card and a calculator.

1	
2	
3	
4	
5	
Total	

Problem 1 - 15 Points **No Partial Credit**

i) Blaise Pascal duplicated Torricelli's barometer using a red Bordeaux wine as the working liquid. What was the height of the wine column for normal atmospheric pressure? The density of the wine was $\rho_{wine} = 0.984 \times 10^3$ kg/m^3 and you can take $P_{atm} = 1.0 \times 10^5$ Pa and g=10 m/s^2 for the acceleration of gravity. (5 Points)

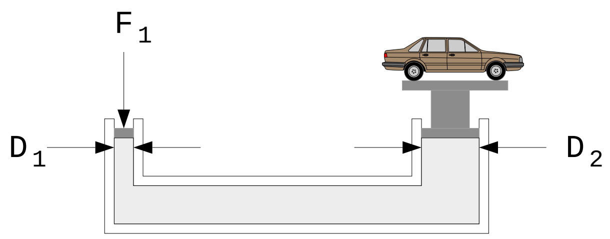
$P_{atm} = \rho_{wine}gh$
$h = P_{atm}/(\rho wine g)$
$= (1.0 \times 10^5 \text{ Nt/m}^2)/[(0.984 \times 10^3 \text{ kg/m}^3)(10 \text{ m/s}^2)]$
$= 10.2 \text{ m} \approx 10. \text{ m}$



a) 5.0 m   b) 1.0 m   c) 0.01 m   d) 10.0 m   e) 9.8 m

ii) In a car lift in a service station, compressed air exerts a force, F_1, on a small piston of diameter, D_1 = 10 cm. This pressure is transmitted to a second piston of diameter, D_2 = 30 cm, which pushes up on the car. What force must the compressed air exert on the first piston in order to lift a car weighing 13,300 Nt? (5 Points)

$F_1/A_1 = F_2/A_2$
⇒ $F_1 = (A_1/A_2)F_2$
$= (D_1/D_2)^2F_2$
$= (1/9)13{,}300 \text{ Nt} = 1478 \text{ Nt} \approx 1480 \text{ Nt}$



a) 1100 Nt   b) 13,300 Nt   c) 26,600 Nt   d) 1480 Nt   e) 4433 Nt

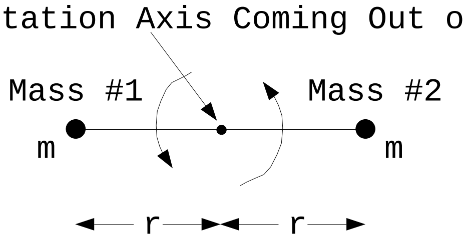
iii) When a weightless spherical balloon is inflated to a volume of 1 m^3 by filling it with gasoline, it weighs 8000 Nt. If it is then placed in seawater, what percentage of the volume of the balloon will be under water? The density of seawater is $\rho_w = 1.025 \times 10^3$ kg/m^3 and you can take g=10 m/s^2 for the acceleration of gravity. (5 points)

$\rho_w V_{disp}g = mg = 8000 \text{ Nt}$
$V_{disp} = 8000 \text{ Nt}/[(1.025 \times 10^3 \text{ kg/m}^3)(10 \text{ m/s}^2)] = 0.78 \text{ m}^3 = 78\% \text{ of } V_{tot}$

a) 72%   b) 78%   c) 100 %   d) 68 %   e) 60 %

Problem 2 - 15 Points   No Partial Credit

Two point masses, each having mass m = 2.5 kg, are connected by a weightless rod whose center is fixed to a pivot point such that each mass is a distance r = 0.5 m from the center of rotation. They are revolving at 1 rpm about the rotation point of the rod, as shown.



i) What is the moment of inertia of this system? (5 points)

$$I = m_1 r_1^2 + m_2 r_2^2$$
$$= 2mr^2$$
$$= 2(2.5\ \text{kg})(0.5\ \text{m})^2 = 1.25\ \text{kg-m}^2$$

a) 5.0 kg-m^2 b) 2.5 kg-m^2 c) 1.25 kg-m^2 d) 3.75 kg-m^2 e) 0.625 kg-m^2

ii) If the distance, r, of each mass to the center of rotation suddenly increases to 1.0 m, what is their new rotation rate? (5 points)

If r increases a factor of 2, then the total moment of inertia will increase a factor of 4 ($I \propto r^2$). Since the angular momentum is conserved here (no external torques), in order for $L = I\omega$ to be constant, ω must decrease a factor of 4, from 1 rpm to 0.25 rpm.

a) 0.25 rpm b) 0.5 rpm c) 1.0 rpm d) 2.0 rpm e) 4.0 rpm

iii) Take the masses to each be a distance of r = 0.5 m from the pivot point and revolving at 1 rpm, as originally specified. Then let the part of the rod connecting mass # 2 to the pivot point suddenly break, leaving mass #1 still connected by the other, remaining, part of the rod to the pivot point. What is the rotation rate of mass # 1? (5 points)

The total angular momentum is the sum of the angular momentum of mass 1 plus that of mass 2. If the rod connecting mass 2 to the pivot point suddenly breaks, then mass 2 will fly off but it will still have the same angular momentum.. Thus, mass 1 will still have its same angular momentum and so mass 1 will still be revolving at 1 rpm.

a) 0.25 rpm b) 0.5 rpm c) 1.0 rpm d) 2.0 rpm e) 4.0 rpm

Problem 3 - 2 Points per question - 10 Points Total   No Partial Credit

Mark the following five questions as TRUE or FALSE.

T [F] **iv)** If the total momentum is conserved in a collision, then the total kinetic energy will be conserved as well.

T [F] **v)** A woman lifts a barbell 2.0 m in 5.0 s. If she lifts it the same distance in 10 s, the work done by her is half as great.

T [F] **ii)** If a phonograph record is dropped onto a freely spinning turntable, then the frictional force between record and turntable decreases the total angular momentum.

[T] F **iii)** In raising an object to a given height by means of a frictionless inclined plane, as compared with raising the object vertically, there is a reduction in the force required.

T [F] **i)** The pressure just at the upper surface of a liquid would increase if the liquid density were increased.

Problem 4 - Partial Credit - 30 Points

A 900 Nt marine in basic training has to complete several events in order to finish the obstacle course. In answering the following questions, you can ignore air resistance and use the acceleration of gravity $g = 10\ m/s^2$.

i) In the first event, the marine climbs a 12 m vertical rope at uniform speed in 6 s. What is his power output, P? (6 Points)

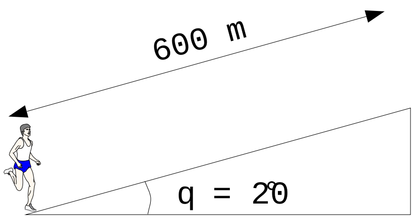
$$P = \Delta W/\Delta t = (F\Delta s)/\Delta t = (900\ Nt)(12\ m)/(6\ s) = 1800\ W$$

ANSWER: P = 1800 Watts

ii) In the second event, he runs a distance of 600 m up a mountain inclined at 20° to the horizontal. How much work, W, does he perform in doing this? (6 Points)

He does work against the force of gravity pulling him down. Thus, he exerts a force upward equal in magnitude to his weight (900 Nt) and the component of his displacement in the up direction is (600 m)sin 20° = 205 m.

$$W = (900Nt)(205\ m) = 184{,}500\ Joules$$



ANSWER: W = 184,500 Joules

iii) In the third event, he has to throw a grenade up into the window of a building which is 8 meters above his hand when he releases the grenade. What is the minimum speed, v, with which he must throw the grenade in order to just make it into the window? (Hopefully, he has a pretty good aim!) (6 Points)

Energy Conservation:

$(1/2)mv^2 = mgh$

$\Rightarrow \quad v = [2gh]^{1/2} = [2(10\ m/s^2)(8\ m)]^{1/2} = 12.6\ m/s$

ANSWER: v = 12.6 m/s.

iv) In the fourth event, he practices how to land when parachuting by running off of a 2 meter high ledge (without a parachute!). If he leaves the ledge with a horizontal speed of 3 m/s, what is his speed, v, when he hits the ground? (Ouch!). (6 Points)

Energy Conservation:

$(1/2)mv_i^2 = (1/2)mv_f^2 + mgh$

$\Rightarrow \quad vf = [v_i^2 - 2gh]^{1/2} = [(3\ m/s)^2 - 2(10\ m/s^2)(-2\ m)]^{1/2} = 7.0\ m/s$

ANSWER: v = 7.0 m/s.

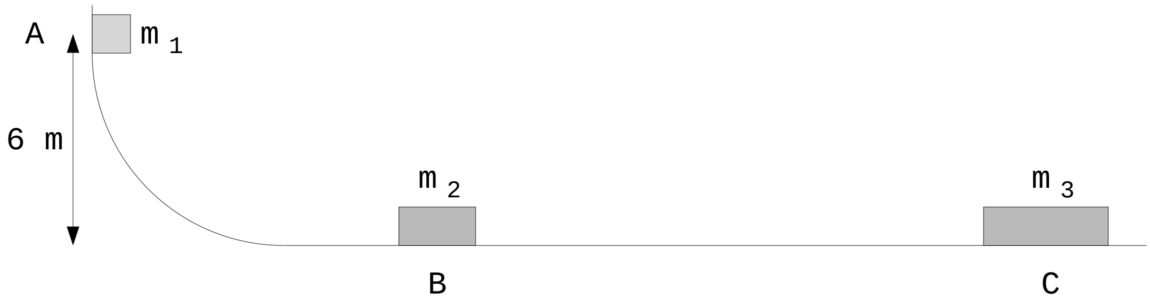
v) In the final event, he must push a stalled jeep through a 40 m wide muddy field. If he exerts a force of 700 Nt on the jeep in order to move it at a constant speed through the mud, how much work, W, does he do? (6 Points)

$W = F\Delta s = (700\ Nt)(40\ m) = 28{,}000$ Joules

ANSWER: W = 28,000 Joules

Problem 5 - 30 Points **Partial Credit**

Consider a frictionless track ABC as shown in the figure. Block 1 of mass $m_1 = 6$ kg is released from rest at point A, which is 6 m above the base of the track. It makes a head-on collision with block 2 of mass $m_2 = 12$ kg at point B, which is also initially at rest. After the collision, block 2 moves toward block 3 of mass $m_3 = 18$ kg at point C, which is al ... peed of 7.0 m/s and block 1 rebounds back up the track towa ... celeration of gravity g=10 m/s^2, and ignore air resistance.



i) What is the speed of block 1 immediately before it collides with block 2? (7 Points)

Energy Conservation:

$mgh = (1/2)mv^2$

$v = [2gh]^{1/2} = [2(10\ m/s^2)(6\ m)]^{1/2} = 11\ m/s$

ANSWER: The speed of block 1 just before the collision is 11 m/s

ii) What is the maximum height, h, to which block 1 will rise above the base of the track after the collision? (8 Points)

Momentum Conservation:

$(6\ kg)(11\ m/s) = (6\ kg)v_1 + (12\ kg)(7\ m/s)$

$v_1 = -3\ m/s$ (i.e., 3 m/s toward the *left*)

$m_1gh = (1/2)m_1v_1^2$

$h = v_1^2/g = (3\ m/s)^2/(10\ m/s^2) = 0.9\ m$

ANSWER: h = 0.9 m

iii) What is the change in total energy of block 1 plus block 2 as a result of the collision? (7 Points)

Just before the collision,

$$E_i = KE_1 = (1/2)(6\ kg)(11\ m/s)^2 = 363\ J$$

Just after the collision,

$$E_f = KE_1 + KE_2 = (1/2)(6\ kg)(3\ m/s)^2 + (1/2)(12\ kg)(7\ m/s)^2 = 321\ J$$

So,

$$\Delta E = \Delta KE = 321\ J - 363\ J = -39\ J$$

ANSWER: ΔE_{total} = - 39 Joules

iv) What is the speed and direction of motion of block 3 just after its elastic collision with block 2? (8 Points)

Conserve momentum:

$$m_2 v_{2i} = m_2 v_{2f} + m_3 v_{3f} \quad (1)$$

or $v_{2f} = v_{2i} - (m_3/m_2)v_{3f}$ (1a)

Conserve energy (elastic collision):

$$(1/2)m_2 v_{2i}^2 = (1/2)m_2 v_{2f}^2 + (1/2)m_3 v_{3f}^2 \quad (2)$$

or $v_{2f}^2 = v_{2i}^2 - (m_3/m_2)v_{3f}^2$ (2a)

Setting v_{2f}^2 from (1a) equal to v_{2f}^2 from (2a) gives

$$v_{2i}^2 - 2(m_3/m_2)v_{2i}v_{3f} + (m_3/m_2)^2 v_{3f}^2 = v_{2i}^2 - (m_3/m_2)v_{3f}^2$$

Solving for v3f gives

$$v_{3f} = [2m_2/(m_2 + m_3)]v_{2i} = [2(12\ kg)/(12\ kg + 18\ kg)](7.0\ m/s) = 5.6\ m/s$$

ANSWER: The speed of block 3 just after its collision with block 2 is 5.6 m/s

The direction of the motion of block 3 is to the [RIGHT] LEFT

EXTRA SPACE FOR CALCULATIONS