Department of Physics

uOttawa
L'Université canadienne
Canada's university

Final Exam
December 10 2015
Closed book exam
Duration: 3 hrs

10 pages
33 questions of equal value
15 correct answers pass the test!

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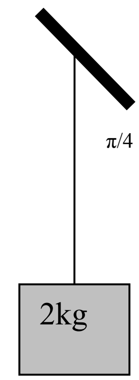
STUDENT SIGNATURE:______________________________

1 Two friends pull on the rope from opposite sides. If they are not moving with respect to each other and one of them pulls with the force of 400N, the tension in the rope is___

a) 400N b) 200N c)100N
d) it is impossible to answer without extra information
e) none of the above



2 2kg mass hangs an the string. String makes angle π/4 with the ceiling.
The tension in the string is:

A 3N B 14.5.4N C 29.4N D 19.6N
E none of the above

3 The position of a particle of mass 2kg is given by $\vec{r} = 3t\vec{i} - t^2\vec{j} + 2\vec{k}$
(t is in seconds and r in meters). The **magnitude** of the instantaneous velocity at t = 2s is:

A 8m/s B 5m/s C $3\vec{i} - 4\vec{j}$ D -8 m/s
E none of the above

4 A particle of mass M, is at the origin while the particle of the mass 4M is at x=1m. The centre of mass of this system is at:

A x=0.1m *B x=0.2m* *C x=0.4 m* D 0.8 m *E none of the above.*

5. The 6 kg grenade explodes inside the horizontal narrow pipe. After the explosion the 2 kg piece is observed to leave from the left side of the pipe with the speed of 50m/s. The second (3kg) piece leaves from the right side of the pipe with speed of 20m/s. What is the speed of the third (last) piece of the grenade, and from which side of the pipe will it emerge?

a) 20m/s, right b) 20m/s, right c) 40m/s, left d) 40m/s , right e) none of the above

6. Cp, the molar specific heat at constant pressure at -200°C of a real diatomic gas is

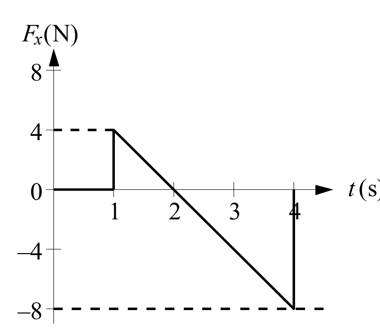
a. $\frac{1}{2}R$. b. R. c. $\frac{3}{2}R$. d. $2R$. e. $\frac{5}{2}R$.

7. A constant force of 12 N in the positive x direction acts on a 4.0-kg object as it moves from the origin to the point (3**i** – 4**j**) m. How much work is done by the given force during this displacement?

A) +60 J B) +84 J C) -48 J D) +36 J E) +none of the above

8. The only force acting on a 2.0 kg object moving along the x axis is shown. If the velocity v_x is -2.0 m/s at $t = 0$, what is the velocity in m/s at t=3.0s?

a. –2.0 b. –4.0 c. –3.0
d. +1.0 e. –5.0



9. The total work done by the gas in one cycle of the thermal engine

A. is always 0.
B. is independent of the path.
C. is equal to the change of internal energy of the gas.
D. is equal to the amount of heat transferred to the gas from the hot reservoir.
E. is equal to the area enclosed by the loop on a PV diagram.

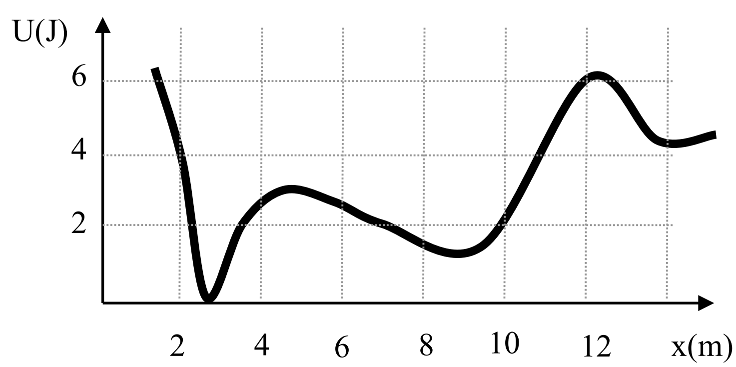
10. A heat pump absorbs 2400 J of heat, while receiving 400 J of mechanical work in each cycle. The coefficient of performance of this pump is:

a.6 b.7 c 8 d. 9 e. none of the above

11. A cycle of the Carnot engine, (operating as heat engine), consists , of the following process in the order given:

a. an isothermal expansion, an isothermal compression, an adiabatic expansion and an adiabatic compression.
b. an adiabatic expansion, an adiabatic compression, an isothermal expansion and an isothermal compression.
c. an isothermal expansion, an adiabatic compression, an isothermal compression and an adiabatic expansion.
d. an isothermal expansion, an adiabatic expansion, an isothermal compression and an adiabatic compression
e. an adiabatic compression, an isothermal compression, an isothermal expansion and an adiabatic expansion.

12 When the particle is at x= 2m it has 2J of kinetic energy, and moves under influence of conservative force whose potential energy is shown in the diagram. What is its kinetic energy, and what is the direction of the force acting on the particle at x=12m?



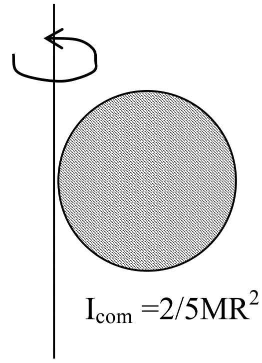
A) K=0J, F is negative
B) K=2J, F is positive
C) K= 3J, F is negative
D) K= 4J, F is negative
E) none of the above

13. A fish weighs 12.0 N at rest. When it is weighed on a spring scale in an elevator accelerating down at $2.60\ \mathrm{m/s^2}$, the scale reads ____ N.

a. 7.3 b. 8.8 c. 11.7 d. 15.2
e. none of the above

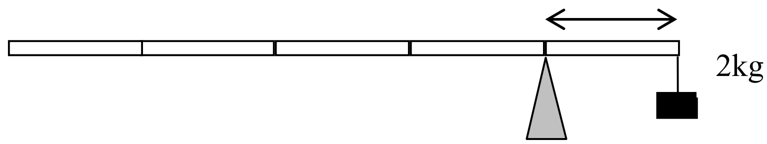
14. Find moment of inertia of the solid sphere (mass =1kg, radius R=0.2m), rotating about the axis as shown.

A 0.028 kgm^2 B 0.020 kgm^2 C 0.014 kgm^2
D 0.056 kgm^2 E none of the above



15 A 2-kg mass is suspended by a massless string from one end of 1-m measuring stick. What is the mass of the stick if it is balanced as shown:

A 0.25 kg B 1.5 kg
C 4/3 kg D 2/3 kg
E none of the above



16 The water level in an open reservoir is maintained at a constant level. What is the exit velocity in an outlet pipe 2.0 m below the water surface?

a. 2.4 m/s
b. 5.4m/s
c. 6.3 m/s
d. 7.7 m/s
e. none of the above.

17 What is the change in entropy in J/K of 0.356 kg of solid lead when it melts at 327°C if the latent heat of fusion of lead is 24.5 kJ/kg?

a. 24.3 b. 14.5 c. 13.8 d. 12.9 e. 15.1

18 Given is the two –dimensional gas made out of diatomic molecules. At sufficiently high temperatures the gas molecules are free to move around within the two dimensional plane, as well as to rotate and oscillate. Which of the following pairs may correctly represent the average energy of single molecule E_{avg}; as well as the C_v of the gas .

a) $E_{avg} = \frac{1}{2}mv_x^2 + \frac{1}{2} mv_y^2$ C_v= R
b) $E_{avg} = \frac{1}{2}mv_x^2 + \frac{1}{2} mv_y^2 + \frac{1}{2}I\omega^2$ C_v= 3/2R
c) $E_{avg} = \frac{1}{2}mv_x^2 + \frac{1}{2} mv_y^2 + \frac{1}{2}I\omega^2$ C_v= 2R
d) $E_{avg} = \frac{1}{2}mv_x^2 + \frac{1}{2} mv_y^2 + \frac{1}{2}I\omega^2 + \frac{1}{2}kr^2 + \frac{1}{2} mv_{osc}^2$ C_v= 5/2R
e) $E_{avg} = \frac{1}{2}mv_x^2 + \frac{1}{2} mv_y^2 + \frac{1}{2} I_1\omega_1^2 + \frac{1}{2} I_2\omega_2^2 + \frac{1}{2}kr^2 + \frac{1}{2}mv_{osc}^2$ C_v= 3R

19 In isovolumetric process 100 J of heat are pumped into each mole of a gas. If the gas has 5 degrees of freedom, how much does its temperature change? Answer in terms of R.

A) 40/R (K) B) 11.43/R (K) C) 6.4/R (K) D) 8.0/R(K) E) none of the above

20 Determine the minimum area of a flat ice floe 1.0 meter thick, if it is to support a 4000-kg car above seawater. (ρ_{ice} = 920 kg/m^3, ρ_{sea} = 1020 kg/m^3.)

a. 20 m^2 **b.** 40 m^2 **c.** 60 m^2 **d.** 80 m^2 **e.** none of the above

21 An object is thrown vertically upward in such a way that it has a speed of 20 m/s when it reaches two thirds of its maximum height above the launch point. Determine this maximum height.

A) 32 m B) 48 m C) 61m D) 96 m E) none of the above

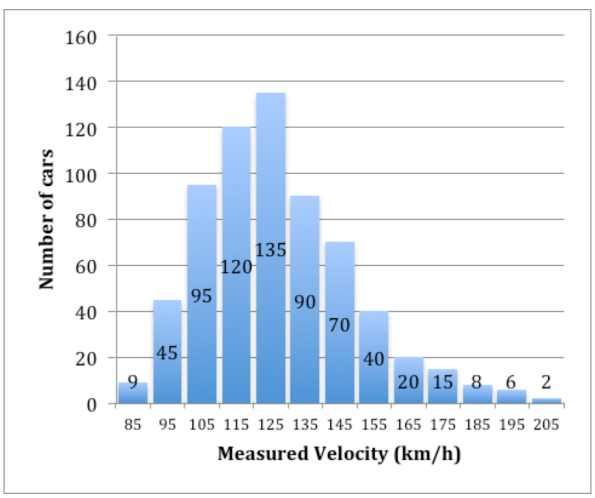
22 A solid, uniform cylinder of mass 2.0 kg and radius 1.7 m rolls without slipping down an inclined plane of height 7.0 m . What is the angular velocity of the sphere at the bottom of the inclined plane?

A 5.6rad/s A 5.8 rad/s B 7.9 rad/s C 9.0 rad/s E none of the above

23 A wheel rotating about a fixed axis with a constant angular acceleration of 2.0 rad/s^2 turns through 2.4 revolutions during a 1.0-s time interval. What is the angular velocity at the end of this time interval?

a. 9.3 rad/s **b.** 9.5 rad/s **c.** 12.7rad/s **d.** 16.01 rad/s **e.** none of the above

24 The distribution of car speeds measured by a Police patrol for a particular stretch of the 401 highway between Kingston and Ottawa is shown on the figure. Each bar represents number of cars in a given interval as a function of the centre value of the interval (for example interval (80<v<90) is represented by 85. Which of the following about the v_{avg} (average speed), v_{rms} [root mean square speed], v_{mp} (most probable speed) and the P (120;140) (probability that the car has speed between 120km/h and 140km/h) are true:



Speed	Number of cars
85	9
95	45
105	95
115	120
125	135
135	90
145	70
155	40
165	20
175	15
185	8
195	6
205	2

A v_{mp} = 123km/h; v_{avg} =127 km/h; v_{rms} =127km/h; P(120, 140) = 0.32
B v_{mp} = 125km/h; v_{avg} =127 km/h; v_{rms} =129km/h; P(120, 140) = 0.34
C v_{mp} = 125km/h; v_{avg} =129 km/h; v_{rms} =127km/h; P(120, 140) = 0.34
D v_{mp} = 115km/h; v_{avg} =123 km/h; v_{rms} =125km/h; P(120, 140) = 0.32
E none of the above

25 A potter's wheel (a solid, uniform disk) of mass 6.1 kg and radius 0.65 m spins about its central axis. A 2.1 kg lump of clay is dropped onto the wheel at a distance 0.41 m from the axis. It sticks to the wheel and rotates with it Calculate the moment of inertia of the system of wheel and the clay (treat a clay lump as a point mass).

A 1.3 kg · m^2 B 0.40 kg · m^2 C 1.6 kg · m^2 D 2.2 kg · m^2
E none of the above

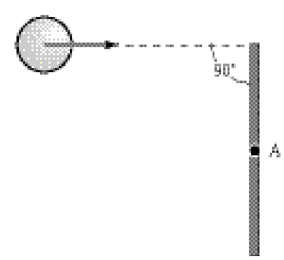
26 Determine the change in entropy (in J/K) when 5.00 moles of an ideal gas at 0°C are compressed isothermally from an initial volume of 100 cm^3 to a final volume of 25 cm^3.

a. –46 **b.** –52 **c.** –71 **d.** –67 **e.** none of these answers

27 Five moles of an ideal gas expands isobaricaly at 1000kPA from 2liter to five times its initial volume. Find the heat flow into the system.

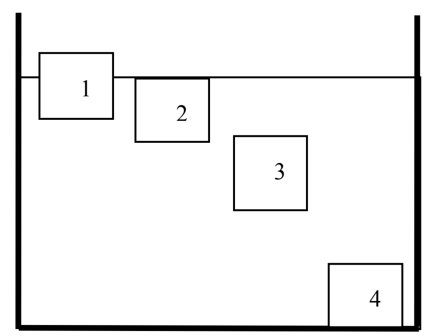
A) 2.0×10^4 J B) 1.0×10^4 J C) 6.7×10^4 J D) 2.9×10^3 J E) none of the above

28. A thin rod of mass *M* and length *L* is struck at one end by a ball of clay of mass *m*, moving with speed *v* as shown in the figure. The ball sticks to the rod. After the collision, the angular momentum of the clay-rod system about A, the midpoint of the rod, is



a. $(m + M/3)(vL/2)$
b. $(m + M/12)(vL/2)$
c. $(m + M/6)(vL/2)$
d. $mvL/2$
e. mvL

29 Four objects of the same volume are placed carefully in the container filled with water (shown on the figure). Once placed there, none of the objects is moving with respect to the water. Which of the following statements about the masses of these objects is correct?



A) m(1) = m(2) < m(3) ≤ m(4)
B) m(1) < m(2) < m(3) < m(4)
C) m(1) < m(2) = m(3) < m(4)
D) m(1) < m(2) = m(3) = m(4)
E) m(1) < m(2) = m(3) ≤ m(4)

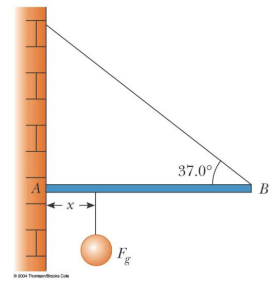
30 A 12-g bullet moving horizontally strikes and remains in a 3.0-kg block initially at rest on the edge of a table. The block, which is initially 100 cm above the floor, strikes the floor a horizontal distance of 120 cm from its initial position. What was the initial speed of the bullet?

a. 0.67km/s
b. 0.75 km/s
c. 0.81 km/s
d. 0.87 km/s
e. none of the above

31 Ten kg of water at 0°C is mixed with ten kg of water at 100°C. The change in entropy in cal/K of the system is

a. 1000 b. 480. c. –720. d. 240 e. none of the above

32 One end of a uniform 4.00-m-long rod of weight F_g is supported by a cable. The other end rests against the wall, where it is held by friction, as in Figure P12.23. The coefficient of static friction between the wall and the rod is $\mu_s = 0.500$. Determine the minimum distance x from point A at which an additional weight F_g (the same as the weight of the rod) can be hung without causing the rod to slip at point A.



A) 1.45m B) 1.96m C)2.24m D) 2.82m
E) none of the above

33. The Boltzmann energy distribution is given by: $P(E) = const\sqrt{E}e^{-\frac{E}{kT}}dE$

What is the most probable energy in this distribution?

A) kT B) 1/2 kT C) 3/2 kT D) 5/2 kT E) none of the above

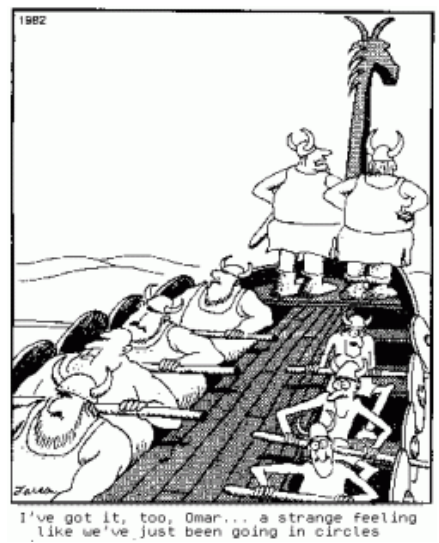
THE END!

You've made it!

To all of you who celebrate it,

I wish you Merry Christmas!

Happy New Year to everyone else!



Mechanics

$$v_x = \frac{dx}{dt} \qquad \vec{v} = \frac{d\vec{r}}{dt}$$

$$a_x = \frac{dv_x}{dt} \qquad \vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{r}_f = \vec{r}_o + \vec{v}_o t + \frac{1}{2}\vec{a}\,t^2$$

$$a_t = \frac{dv}{dt} \qquad a_c = \frac{v^2}{r}$$

$$\vec{F} = m\vec{a} \qquad \vec{F}_o = -b\vec{v}$$

$$f = \mu N \qquad R = \frac{1}{2}D\rho A v^2$$

$$F_B = \rho_l V.g$$

$$\vec{F} = -k\vec{x}$$

$$W = \int \vec{F}.d\vec{s}$$

$$k = \frac{mv^2}{2} \qquad U_g = mgh \qquad U_e = \frac{1}{2}kx^2$$

$$\vec{P} = m\vec{v} \qquad \vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{r}_{CM} = \frac{\sum m_i \vec{r}_i}{M} \qquad r_{CM} = \frac{\int r dm}{M}$$

$$V = \frac{4}{3}\pi r^3 \qquad A = 4\pi r^2 \qquad A = \pi r^2 \qquad C = 2\pi r$$

Fluid Mechanics:

$$p = p_o + \rho g h \qquad A_1 v_1 = A_2 v_2 \qquad p_o + \rho g y + \frac{1}{2}\rho v^2 = const$$

Rotational motion About a Fixed Axis

Angular speed $\omega = d\theta / dt$

Angular acceleration $\alpha = dw / dt$

Net torque $\sum \tau = I\alpha$

If $\alpha = const. \begin{cases} \omega_f = \omega_i + \alpha t \\ \theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2 \\ \omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i) \end{cases}$

Work $W = \int_{\theta_i}^{\theta_f} \tau \quad d\theta$

Rotational kinetic energy $K_R = \frac{1}{2} I\omega^2$

Power $P = \tau\,\omega$

Angular momentum $L = I\omega$

Net torque $\sum \tau = dL / dt$

Circular Hoop $I_{CM} = MR^2$

Hollow cylinder $I_{CM} = \frac{1}{2} M(R_1^2 + R_2^2)$
where R_1: inner radius, R_2: outer radius

Solid cylinder or disc $I_{CM} = \frac{1}{2} MR^2$

Thin Rectangle $I_{CM} = \frac{1}{12} M(a^2 + b^2)$

Long thin rod with rotational axis through center $I_{CM} = \frac{1}{12} ML^2$

Long thin rod with rotational axis through edge $I_{CM} = \frac{1}{3} ML^2$

Solid sphere $I_{CM} = \frac{2}{5} MR^2$

Thin spherical shell $I_{CM} = \frac{2}{3} MR^2$

THERMODYNAMICS

Probability of finding the speed of a particle in the range (v;v+dv)is:

$$P(v)dv = 4\pi\left[\frac{1}{2\pi}\frac{m}{kT}\right]^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}} dv$$

$$v_{MP} = \left[\frac{2kT}{m}\right]^{\frac{1}{2}} \qquad v_{rms} = \left[\frac{3kT}{m}\right]^{\frac{1}{2}} \qquad v_{avg} = \left[\frac{8kT}{\pi m}\right]^{\frac{1}{2}}$$

$$p = \frac{1}{3}\rho < v^2 > \qquad \rho = \frac{Nm}{V}$$

Integrals:

$$\int_0^{+\infty} e^{-ax^2} dx = \frac{1}{2}\sqrt{\frac{\pi}{a}} \qquad \int_0^{+\infty} xe^{-ax^2} dx = \frac{1}{2a} \qquad \int_0^{+\infty} x^2 e^{-ax^2} dx = \frac{1}{4}\sqrt{\frac{\pi}{a^3}} \qquad \int_0^{+\infty} x^3 e^{-ax^2} dx = \frac{1}{2a^2}$$

$$\int_0^{+\infty} x^4 e^{-ax^2} dx = \frac{3}{8}\sqrt{\frac{\pi}{a^5}} \qquad \int_0^{+\infty} \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$$

ΔEint = Q + W $\qquad$ $pV=nRT$ $\qquad$ $\Delta S = \int \frac{dQ}{T}$

Change	ΔEint	W	Q	ΔS
P = const	$nC_v \Delta T$	$-p(V_f - V_i)$	$nC_p \Delta T$	$nC_p \ln\frac{T_f}{T_i}$
V = const	$nC_v \Delta T$	0	$nC_v \Delta T$	$nC_V \ln\frac{T_f}{T_i}$
T = const	0	$-nRT\ln\frac{V_f}{V_i}$	$nRT\ln\frac{V_f}{V_i}$	$nR\ln\frac{V_f}{V_i}$
Q = 0	$nC_v \Delta T$	$\frac{1}{\gamma - 1}\left(p_f V_f - p_i V_i\right)$	0	0

$pV^\gamma = const.$ $\qquad$ $\gamma = \frac{C_P}{C_V}$ $\qquad$ $C_p - C_v = R$

$$\epsilon_{CRN} = \frac{W}{Q} = \left|\frac{Q_H - Q_L}{Q_H}\right| = 1 - \frac{T_C}{T_H} \qquad \textbf{COP} = \frac{\textbf{what we want}}{\textbf{what we pay for it}}$$

$\Delta L = \alpha L \Delta T$ $\qquad$ $\Delta S = \beta S \Delta T$ $\qquad$ $\Delta V = \gamma V \Delta T$

P = e σ A $T^{4;}$ σ =5.67x 10^{-8}W/($K^4 m^2$) $\qquad$ $P = kA\left|\frac{dT}{dx}\right|$

Q = mcΔT $\qquad$ Q = Lm

c(water) = 4186 J/(kg C); $\qquad$ c(ice) = 2090 J/(kg C); $\qquad$ c(steam) = 2010J/(kg C)

L(melting) = $3.33\text{x}10^5$ J/kg $\qquad$ L (vaporization) = $2.26\text{x}10^6$ J/kg