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Principles of Physics I
PHY1321
PHY1331

Department of Physics

Instructor: Dr. Andrzej Czajkowski
Final Exam
December 14 2013

Closed book exam

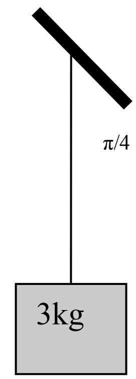
10 pages
33 questions of equal value
15 correct answers pass the test!

Duration: 3 hrs

RETURN ONLY THE SCANTRON SHEET!

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 200N, 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 3kg mass hangs an the string. String makes angle π/4 with the ceiling.
The tension in the string is:

A 3N B 29.4N C 0N D 14.7N 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. A cart of mass M moving at speed v collides with another stationary cart of mass 3M on air track (no friction), and the two stick together after the collision. What is their velocity after colliding?
A 0.5 v B -0.25v C 0.25v D -v E none of the above

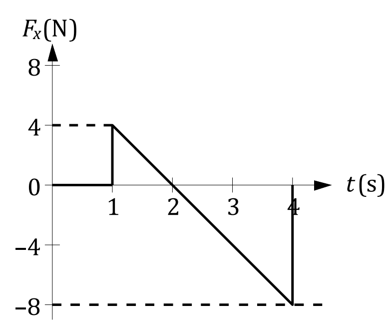
6. The specific heat at constant volume at -200°C of one mole of an ideal diatomic gas is

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 y 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) +57 J E) +72 J

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 $t = 4.0$ s?
a. –2.0 b. –4.0 c. –3.0
d. +1.0 e. –5.0



9. The heat transferred to the gas in one cycle of the thermal engine
   A. is always 0.
   B. is independent of the path.
   C. is the slope of a PV curve.
   D. is equal to the amount of work done by the gas
   E. is the area under the curve of a PV diagram.

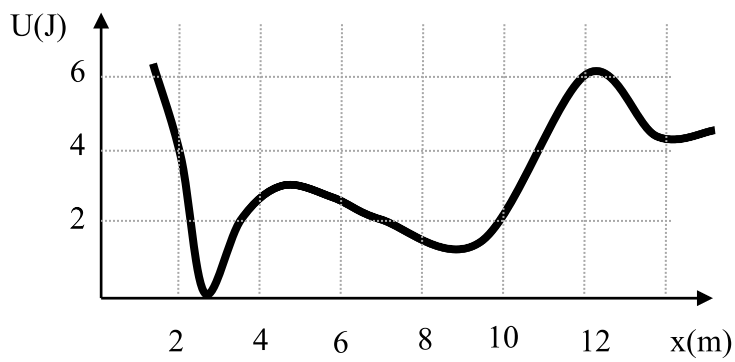
10. A steam engine absorbs 2400 J of heat and performs 1200 J of mechanical work in each cycle. The efficiency of the engine is

a.80% b.60% c.50% d.40% e.20%

11. A Carnot cycle, operating as a heat engine, consists , in the order given, of

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=10m?



A) K=0J, F is positive
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 10.0 N at rest. When it is weighed on a spring scale in an elevator accelerating down at $2.60\ m/s^2$, the scale reads ___ N.
a. 7.35 b. 10.7 c. 11.7 d. 12.7 e. 13.

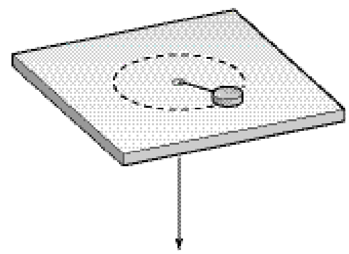
14 A wheel rotating about a fixed axis with a constant angular acceleration of 2.0 rad/s^2 turns through 2.4 revolutions during a 2.0-s time interval. What is the angular velocity at the end of this time interval?

a. 9.5 rad/s **b.** 9.7 rad/s **c.** 9.3 rad/s **d.** 9.1 rad/s **e.** 8.8 rad/s

15 Determine the minimum area of a flat ice floe 1.0 meter thick if it is to support a 2000-kg car above seawater. (r_{ice} = 920 kg/m^3, r_{sea} = 1020 kg/m^3.)

a. 20 m^2
b. 40 m^2
c. 60 m^2
d. 80 m^2
e. 100 m^2

16. A puck on a frictionless air hockey table has a mass of 5.0 g and is attached to a cord passing through a hole in the surface as in the figure. The puck is revolving at a distance 2.0 m from the hole with an angular velocity of 3.0 rad/s. The cord is then pulled from below, shortening the radius to 1.0 m. The new angular velocity (in rad/s) is



a. 4.0
b. 6.0
c. 12
d. 2.0
e. 8.0

17. The water level in a reservoir is maintained at a constant level. What is the exit velocity in an outlet pipe 3.0 m below the water surface?

a. 2.4 m/s
b. 3.0 m/s
c. 5.4 m/s
d. 7.7 m/s
e. 49 m/s

18 A heat pump with a coefficient of performance of 5.5 absorbs heat from the atmosphere at a rate of 45 kW. At what rate is it doing work?
A 6 kW B 147 kW C 248 kW
D 8.2 kW E none of the above

19 Five moles of an ideal gas expands isobaricaly at 1000kPA from 1liter to five times its initial volume. Find the heat flow into the system.

A) 2.5×10^4 J B) 1.0×10^4 J C) 6.7×10^4 J D) 2.9×10^3 J E) 7.0×10^3 J

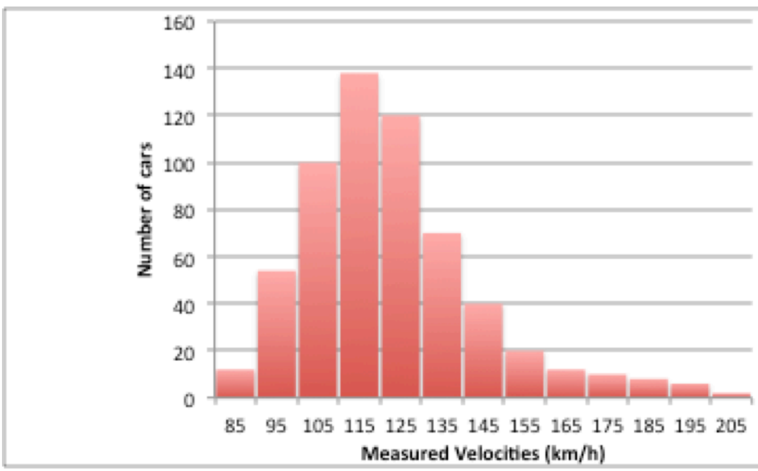
20 *A solid, uniform sphere of mass 2.0 kg and radius 1.7 m rolls without slipping down an inclined plane of height 7.0 m. What is the angular velocity of the sphere at the bottom of the inclined plane?*

A 5.8 rad/s *B 9.9 rad/s* *C 11.0 rad/s* *D 7.0 rad/s* *E none of the above*

21 In isovolumetric process 20 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

22 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. Which of the following conclusions 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	12
95	54
105	100
115	138
125	120
135	70
145	40
155	20
165	12
175	10
185	8
195	6
205	2

A v_{mp} = 123km/h; v_{avg} =125 km/h; v_{rms} =127km/h; P(120, 140) = 0.16
B v_{mp} = 123km/h; v_{avg} =125 km/h; v_{rms} =127km/h; P(120, 140) = 0.32
C v_{mp} = 115km/h; v_{avg} =123 km/h; v_{rms} =125km/h; P(120, 140) = 0.16
D v_{mp} = 115km/h; v_{avg} =123 km/h; v_{rms} =125km/h; P(120, 140) = 0.32
E none of the above

23. A 0.28 kg stone you throw rises 34.3 m in the air. The impulse your hand receives from the stone while it catches the stone as it falls back is

A. $2.7\,N\cdot s$, up. **B.** $2.7\,N\cdot s$, down. C. $7.3\,N\cdot s$, up.
D. $7.3\,N\cdot s$, down. **E.** $9.6\,N\cdot s$, up.

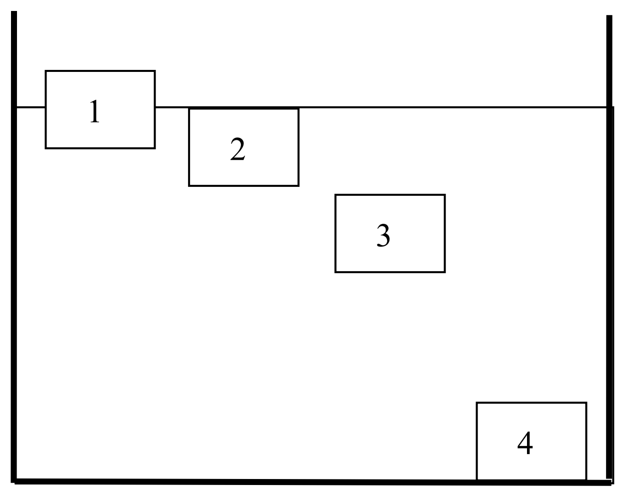
24 Given is the two –dimensional gas made out of diatomic molecules. At sufficiently high temperatures the gas molecules are free to move around within the two dimensional plane, as well as to rotate and oscillate. Which of the following pairs correctly represents the average energy of single molecule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

25. A 0.60 kg mass is swung in a vertical circle. It is fastened to a string 0.35 m long. What is the tension in the string in N at the top of the circle when the speed of the mass at that point is 5.5 m/s?

A. 35 B. 46 C. 49 D. 58 E. 61

26 Four objects of the same mass are placed carefully in the container filled with water (shown on the figure). None of the objects is moving with respect to the water. Which of the following statements about the volumes of these objects is true:



A) V(1) = V(2) < V(3) < V(4)
B) V(1) > V(2) > V(3) >V(4)
C) V(1) > V(2) = V(3) ≥ V(4)
D) V(1) > V(2) = V(3) = V(4)
E) V(1) < V (2) = V(3) ≤ V(4)

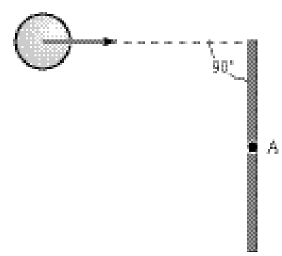
27. A 12-g bullet moving horizontally strikes and remains in a 3.0-kg block initially at rest on the edge of a table. The block, which is initially 80 cm above the floor, strikes the floor a horizontal distance of 120 cm from its initial position. What was the initial speed of the bullet?

a. 0.68 km/s
b. 0.75 km/s
c. 0.81 km/s
d. 0.87 km/s
e. 0.41 km/s

28 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 20 cm^3.

a. −191 **b.** −52 **c.** −71 **d.** −67 **e.** −208

29. 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



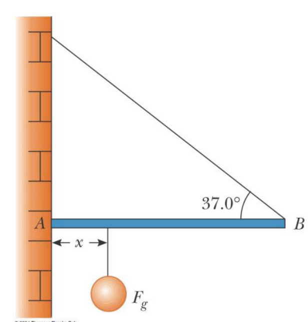
a. $(m + M/3)(vL/2)$
b. $(m + M/12)(vL/2)$
c. $(m + M/6)(vL/2)$
d. $mvL/2$
e. mvL

30 *A 25 g lead bullet at 0°C moves at 375 m/s and strikes a block of ice at 0°C. What quantity of ice in kg is melted if all of the kinetic energy of the bullet is converted to heat? The block of ice does not move. (The latent heat of fusion of ice is 80 kcal/kg and the specific heat of lead is* $0.0305\ \text{kcal/kg}\cdot°\text{C}$. $1\ \text{cal} = 4.186\ \text{J}$ *)*

A 4.21×10^{-3} *B* 5.89×10^{-3} *C* 4.98×10^{-3} *D* 5.25×10^{-3}
E 5.18×10^{-3}

31 *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.*
A 1.3 $kg \cdot m^2$ *B* 0.40 $kg \cdot m^2$ *C* 2.2 $kg \cdot m^2$ *D* 1.6 $kg \cdot m^2$
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. *A 5-g coin, is dropped from a 300-m building. Due to the air resistance it reaches a terminal (max) velocity of 45 m/s, and the rest of the energy is converted to heating the coin, what is the change in temperature (in K) of the coin? (The specific heat of copper is 387 J/kg °C.) What is the entropy change associated with this heating (coin initial temperature was 300K)?*

A) ΔT=9K; ΔS= 0.062J/K *B) ΔT=2K; ΔS=0.023J/K* <u>*C)ΔT= 5K; ΔS= 0.032J/K*</u>
D ΔT=21K; ΔS=0.090J/K *E none of the above*

Mechanics

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

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

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

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

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

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

$$F_B = \rho_l V.g$$

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

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

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

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

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

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

Fluid Mechanics:

$p = p_o + \rho gh$ $\quad A_1 v_1 = A_2 v_2$ $\quad p_o + \rho gy + \frac{1}{2}\rho v^2 = const$

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	$nC_v\Delta T$	$\frac{1}{\gamma-1}\left(p_fV_f - p_iV_i\right)$	0	0

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

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

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

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

$Q = mc\Delta T$ $\qquad$ $Q = Lm$

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

L(melting) = 3.33×10^5 J/kg $\qquad$ L (vaporization) = 2.26×10^6 J/kg