



uOttawa

L'Université canadienne  
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PHY1321A; PHY1321A; PHY1331A; PHY1331B

Instructor: Dr. Andrzej Czajkowski

Final Exam

DECEMBER 2017

Closed book exam

Duration: 3 hrs.

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STUDENT SIGNATURE: \_\_\_\_\_ DATE: \_\_\_\_\_

PLEASE NOTE:

Letters: S M T placed as superscripts next to the question number denote the intended level of difficulty of each question:

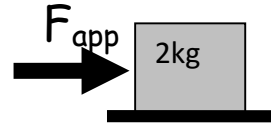
S-straightforward / M moderate / T- time consuming

MECHANICS OF MATERIAL POINT (Kinematics, Dynamics, Work and Energy, Linear Momentum)

- 1.<sup>s</sup> A small package is released from the gondola of a hot air balloon, when it is +35 meters above the ground while the balloon is moving up with the velocity of +2m/s, and acceleration of +0.5m/s<sup>2</sup>, all with respect to the ground. What is the package velocity (v) and acceleration (a) (with respect to the ground) at the moment it is released from the gondola?  
 A) v= + 2m/s; a= + 0.5m/s<sup>2</sup>  
 B) v= + 2m/s; a= - 9.4m/s<sup>2</sup>  
 C) v= - 2m/s; a= - 0.5m/s<sup>2</sup>  
D) v= + 2m/s; a= - 9.8m/s<sup>2</sup>  
 E) none of the above

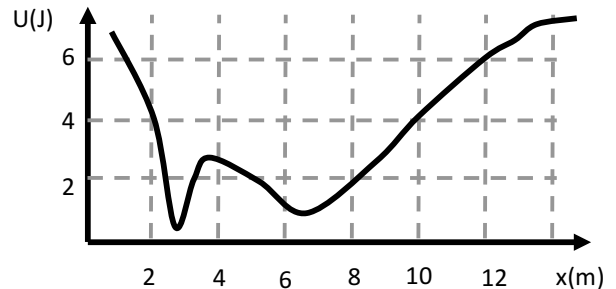
- 2.<sup>s</sup> A 2 kg mass is suspended on a string. The tension in the string is:  
 A) 2.0N      B) 29.4N      C) 0N      D) 19.6N      E) 196 N

- 3.<sup>s</sup> 2 kg mass being acted on by the  $F_{app} = 10 \text{ N}$  as it rests on the flat surface as shown. The force of friction acting on this mass is \_\_\_\_  
 A) 2N      B) 10N      C) 0N      D) 19.6N  
 E) there not enough information to answer.



- 4.<sup>s</sup> A desk is pushed across the horizontal floor at constant velocity by force F= 160 N force directed downwards at an angle of 48° to the horizontal. How much work (in J) is done by the force F, when the desk has moved by 1.4 m forward?  
 A) 150      B) 170      C) 190      D) 210      E) 230

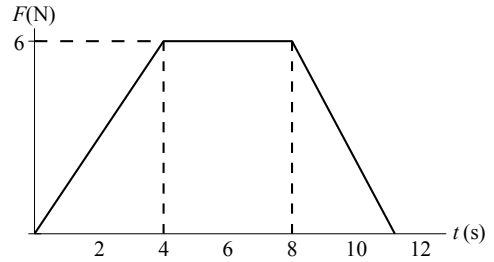
- 5.<sup>s</sup> Particle moves under the influence of conservative force whose potential energy is shown in the diagram. At t=0 particle has K=4J at x= 8m. What is the kinetic energy of the particle at x=2m, what is the direction of the force acting on the particle at this point?  
 A) K(2m) = 6J; F<sub>x</sub> >0  
 B) K(2m) = 6J; F<sub>x</sub> <0  
C) K(2m) = 2J; F<sub>x</sub> >0  
 D) K(2m) = 2J; F<sub>x</sub> <0  
 E) K(2m) = 2J; F<sub>x</sub> depends on which way is the particle moving



- 6.<sup>s</sup> The position of a particle of mass 2g is given by  $\vec{r} = 3t\vec{i} - 4t^2\vec{j} + 2\vec{k}$  (t is in seconds and r in meters). The magnitude of instantaneous velocity and the magnitude of instantaneous acceleration at t = 2s are:  
A) |v| = 16.3 m/s      |a| = 8.0m/s<sup>2</sup>  
 B) |v| = 8.5 m/s      |a| = 16.3/s<sup>2</sup>  
 C) |v| = 16.3 m/s      |a| = 16.3m/s<sup>2</sup>  
 D) |v| = 8.5 m/s      |a| = 8.0m/s<sup>2</sup>  
 E) none of the above

7. <sup>S</sup> A 1.0 kg body, initially at rest, is acted on by the horizontal force shown in the graph. What is its speed in m/s when  $t=11s$ ?

A) 18                      B) 26                      C) 27  
D) 36                      E) 45



8. <sup>M</sup> Donna wants to whirl a 0.64 kg stone on a string at the greatest possible speed, but the string will break if a force greater than 24 N is applied. If the maximum speed Donna can achieve is 3.0 m/s, how long should the string be?

A) 0.080 m              B) 0.16 m              C) 0.24 m              D) 0.32 m              E) 0.64 m

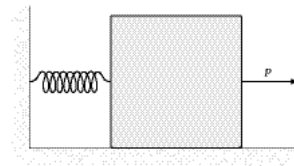
9. <sup>M</sup> A bullet of mass  $m=80g$  is fired horizontally into a block of mass  $M = 4kg$  resting on a flat frictionless surface. After the collision, the block with the bullet enter a rough patch ( $\mu_{kin}=0.3$  ;  $\mu_{stat}=0.5$ ), and travels distance of 1.5 meter on it, before stopping. The initial velocity (before the collision) of the bullet is:

A) 201m/s              B) 178 m/s              C) 169m/s              D) 151m/s              E) none of these answers

10. <sup>M</sup> A race car starts from rest on a circular track. The car increases its speed at a constant rate  $a_t$  as it goes once around the track in the counterclockwise direction. Find the angle that the total acceleration of the car makes with the radius of the circle, at the moment when the car completes first half of the circle.

A) 9.04°              B) 4.55°              C) 3.14°              D) ) 0.08°              E) none of the above

11. <sup>T</sup> A 12-kg block on a horizontal frictionless surface is attached to a light spring (force constant = 0.80 kN/m). The spring is initially stretched from the equilibrium position by a force  $P$  (magnitude  $P=160N$ ) applied to the mass as shown. The block is released and it is free to move under elastic force of the spring. What is the speed of the block when it is 13 cm from its equilibrium position?



A) 0.78 m/s  
B) 0.81 m/s  
C) 0.91 m/s  
D) 1.24 m/s  
E) none of the above

12. <sup>T</sup> The 1kg grenade is thrown vertically up with initial speed of 25m/s. It explodes in a mid-air in such a way that both of its fragments have no horizontal components of velocity after the explosion. If the maximum height reached by the 0.2 kg fragment is equal to 40m, what is the maximum height reached by the 0.8 fragment?

A) 28.2m              B) 29.9m              C) 31.9m              D) 32m              E) none of these answers

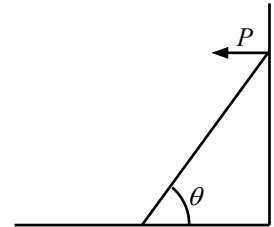
ROTATIONAL MECHANICS OF RIGID BODY

- 13.<sup>S</sup> A potter's wheel (a solid, uniform disk) of mass 6.1 kg and radius 0.65 m spins about its central axis. A small (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 "wheel plus clay" system.  
 A)  $1.3 \text{ kg} \cdot \text{m}^2$     B)  $0.40 \text{ kg} \cdot \text{m}^2$     C)  $2.2 \text{ kg} \cdot \text{m}^2$     D)  $1.6 \text{ kg} \cdot \text{m}^2$     E) none of the above

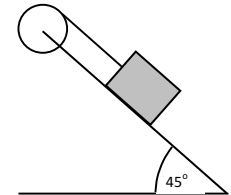
- 14.<sup>M</sup> A wheel rotating about a fixed axis with a constant angular acceleration of  $2.0 \text{ rad/s}^2$  turns through 4.0 revolutions during a 2.0-s time interval. What is the angular velocity at the end of this time interval?  
 A) 4.0 rad/s    B) 7.1 rad/s    C) 9.5 rad/s    D) 14.6 rad/s    E) none of the above

- 15.<sup>M</sup> A ladder of mass  $m$  leans against a frictionless wall that exerts a normal force  $P$  on the ladder. The coefficient of static friction between the ground and the ladder is  $\mu_s$ . The magnitude of the normal force  $P$  of the wall on the ladder is

A  $P = \frac{mg}{2 \sin \theta}$ .                      B  $P = \frac{mg}{2 \cos \theta}$ .                      C  $P = \frac{mg}{2 \tan \theta}$ .  
 D  $P = \frac{mg}{2} \tan \theta$ .                      E  $P = \frac{\mu_s mg}{2} \tan \theta$ .

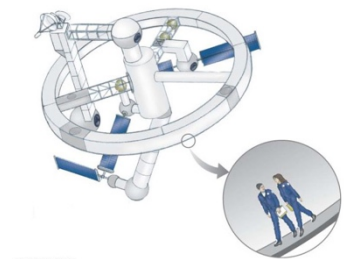


- 16.<sup>T</sup> A block of mass  $=2\text{kg}$  can slide down a frictionless 45degree incline but it is connected to a pulley of mass  $M =4\text{kg}$  and radius  $R=0.5\text{m}$ , as shown. The pulley can be treated as a disk ( $I_{\text{com}} = 1/2mR^2$ ). Angular acceleration of the pulley is:  
A  $6.92\text{rad/s}^2$     B  $7.83\text{rad/s}^2$     C  $3.46\text{rad/s}^2$     D  $3.91 \text{ rad/s}^2$   
 E  $9.02 \text{ rad/s}^2$

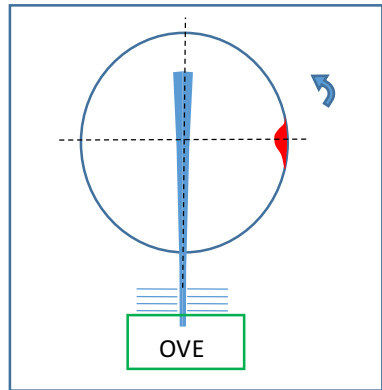


- 17.<sup>T</sup> A solid, uniform sphere of mass 2.0 kg and radius 1.7 m rolls without slipping down an inclined plane of height 7.0 m. What is the angular velocity of the sphere at the bottom of the inclined plane?  
A 5.8 rad/s    B 9.9 rad/s    C 11.0 rad/s    D 7.0 rad/s    E none of the above

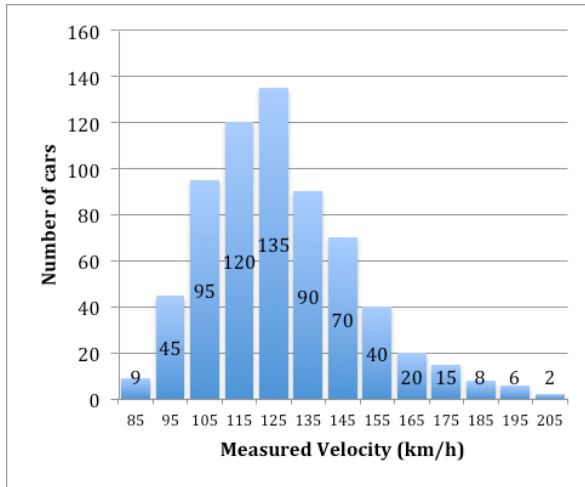
- 18.<sup>T</sup> A space station shaped like a giant wheel has a radius of 100 m and a moment of inertia of  $5.00 \times 10^8 \text{ kg} \cdot \text{m}^2$  when un-occupied. A crew of 150 is living on the rim, and the station's rotation about its center causes the crew to experience an apparent free-fall acceleration of  $1g$  ( $g=9.8\text{m/s}^2$ ). When 140 people move to the center of the station for a union meeting, the angular speed changes. What apparent free-fall acceleration is experienced by the managers remaining at the rim? Assume that the average mass for each inhabitant is 65.0 kg and treat them as point masses.  
 a) 0.3g                      b) 1.0 g                      c) 1.2 g                      d) 1.4 g  
 e) none of the above



## THERMODYNAMICS

- 19.<sup>S</sup> In thermodynamics the work done in the expansion from an initial to a final state of a gas
- depends only on the initial and final states.
  - is independent of the path.
  - is the slope of a PV curve.
  - equals  $P(V_F - V_i)$
  - is the area under the curve of a PV diagram.
- 20.<sup>S</sup> A gasoline engine absorbs 2500 J of heat and performs 1000 J of mechanical work in each cycle. The efficiency of the engine is
- a.80%      b.60%      c.50%      d.40%      e.20%
- 21.<sup>S</sup> Five moles of an ideal gas expands isothermally at 100°C to five times its initial volume. Find the heat flow into the system.
- A)  $2.5 \times 10^4$  J    B)  $1.1 \times 10^4$  J    C)  $6.7 \times 10^3$  J    D)  $2.9 \times 10^3$  J    E)  $7.0 \times 10^2$  J
- 22.<sup>S</sup> Find the change in entropy (in J/K) when 5.00 moles of an ideal monatomic gas are allowed to expand isobarically from an initial volume of 20 cm<sup>3</sup> to a final volume of 100 cm<sup>3</sup>.
- A)52      B)67      C)100      D)152      E)167
- 23.<sup>M</sup> A bubble having a diameter of 1.00 cm is released from the bottom of a swimming pool where the depth is 5.00 m. What will the diameter of the bubble be when it reaches the surface? The temperature of the water at the surface is 20.0°C, whereas it is 15.0°C at the bottom.  
(Take the density of water as  $1.00 \times 10^3$  kg/m<sup>3</sup>, and  $p_{\text{atm}}=101\text{kPa}$ ).
- A 1.05cm      B 1.15 cm      C 1.51cm      D 1.65cm      E none of the above
- 24.<sup>M</sup> A glass window pane has an area of 3.00 m<sup>2</sup> and a thickness of 0.600 cm. If the temperature difference between its faces is 25.0°C, what is the rate of energy transfer by conduction through the window. (thermal conductivity of glass:  $k_{\text{glass}}=0.8\text{W}/(\text{m C})$ )
- A) 5000W;      B) 7500W;      C)10000W;      D)15000W;      E) none of the above
- 25.<sup>M</sup> In a version of Stern- Zartman Experiment, a beam of silver atoms emerges from the nozzle of an oven and enters the rotating glass cylinder (diameter: 1m) through a single slot as shown. The atoms travel along the cylinder's diameter, while the cylinder rotates counter-clockwise at 112 rev/s.  
As result, the atoms are deposited on the side wall of the cylinder forming a silver layer. After the experiment is concluded, the cylinder is removed from vacuum system and the thickness of the silver atoms deposit is evaluated. It turns out, that the deposit is the thickest at the point at exactly 90° with respect to the main beam axis. (Main axis is defined by the beam direction). Use this information to find the temperature of the silver gas in the beam. (Molar mass of the silver is 108g.)
- 
- A) 767°C      B) 1031°C      C)1040 °C      D)1304 °C      E) none of the above

26. <sup>M</sup> 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 (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  $v_{mp} = 123\text{km/h}$ ;  $v_{avg} = 127\text{ km/h}$ ;  $v_{rms} = 127\text{km/h}$ ;  $P(120, 140) = 0.32$   
B  $v_{mp} = 125\text{km/h}$ ;  $v_{avg} = 127\text{ km/h}$ ;  $v_{rms} = 129\text{km/h}$ ;  $P(120, 140) = 0.34$   
 C  $v_{mp} = 125\text{km/h}$ ;  $v_{avg} = 129\text{ km/h}$ ;  $v_{rms} = 127\text{km/h}$ ;  $P(120, 140) = 0.34$   
 D  $v_{mp} = 115\text{km/h}$ ;  $v_{avg} = 123\text{ km/h}$ ;  $v_{rms} = 125\text{km/h}$ ;  $P(120, 140) = 0.32$   
 E none of the above

27. <sup>M</sup> The definition of the entropy  $\Delta S = k \ln W$  used in the context of II Law of Thermodynamics implies that:
- the entropy of the Universe remains constant.
  - the arrow of time is imposed by the observer.
  - an arbitrary system will not evolve spontaneously from a more complex form to a less complex form.
  - an arbitrary system will evolve from a state of lower probability (low W) to a state of higher probability (high W).
  - none of the above

28. <sup>M</sup> The Boltzmann energy distribution is given by:  $P(E) = \text{const} \sqrt{E} e^{-\frac{E}{kT}}$  ?

What is the most probable energy in this distribution?

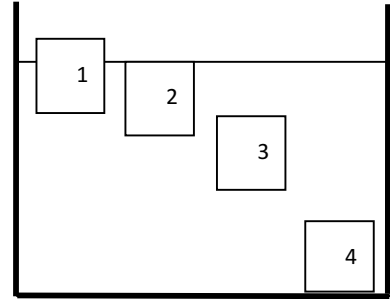
- A)  $kT$       B)  $1/2 kT$       C)  $3/2 kT$       D)  $5/2 kT$       E) none of the above

29. <sup>T</sup> A 20 kg sample of mercury is completely solidified and liberates 231.6 kJ of energy. What is the initial temperature of the mercury? What is the entropy change  $\Delta S$  of mercury in this process? (The melting point of mercury is 234K, the heat of fusion of mercury is 11.3 kJ/kg, and the specific heat of mercury is 140 J/kg•K.)

- A  $T=240\text{ K}$        $\Delta S=-995\text{J/K}$   
B  $T=236\text{ K}$        $\Delta S=-990\text{J/K}$   
 C  $232.0\text{ K}$        $\Delta S=-979\text{J/K}$   
 D  $236\text{ K}$        $\Delta S=-966\text{J/K}$   
 E none of the above

## FLUIDS

- 30.<sup>M</sup> 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)  $m(1) = m(2) < m(3) \leq m(4)$   
 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)  $m(1) < m(2) = m(3) \leq m(4)$



- 31.<sup>M</sup> Determine the minimum area of a flat ice floe (1.0 meter thick), if it is to support a 1000-kg car above seawater. (Density of ice =  $920 \text{ kg/m}^3$ , density of Seawater =  $1020 \text{ kg/m}^3$ .)
- A)  $10 \text{ m}^2$       B)  $20 \text{ m}^2$       C)  $40 \text{ m}^2$       D)  $80 \text{ m}^2$       E) none of the above
- 32.<sup>T</sup> A hole is punched in a full milk carton, 10 cm below the top. What is the initial velocity of outflow?
- A)  $1.4 \text{ m/s}$       B)  $2.0 \text{ m/s}$       C)  $2.8 \text{ m/s}$       D)  $3.9 \text{ m/s}$       E)  $2.8 \text{ m/s}$

## Special Topics

- 33.<sup>S</sup> Finish the sentence to obtain correct statement.  
 "According to the Noether's Theorem, the conservation of angular momentum is a result of the physical system's \_\_\_\_\_."
- A) invariance under translation by a spatial vector.  
 B) invariance under translation by a time-vector.  
 C) invariance under rotation about an axis.  
 D) invariance under gauge transformation.  
 E) invariance under time reversal transformation.

Mechanics

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

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

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


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

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

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

$$F_B = \rho_l V \cdot g$$

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


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

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

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

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


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$$V = \frac{4}{3} \pi r^3$$

$$A = 4\pi r^2$$

$$A = \pi r^2$$

$$C = 2\pi r$$

Fluid Mechanics:

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


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Rotational motion About a Fixed Axis

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Angular speed  $\omega = d\theta/dt$ Angular acceleration  $\alpha = d\omega/dt$ Net torque  $\sum \tau = I\alpha$ 

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

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

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

Power  $P = \tau \omega$ Angular momentum  $L = I\omega$ Net torque  $\sum \tau = dL/dt$ 

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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:

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

$$v_{MP} = \left[ \frac{2kT}{m} \right]^{\frac{1}{2}}$$

$$v_{rms} = \left[ \frac{3kT}{m} \right]^{\frac{1}{2}}$$

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

$$p = \frac{1}{3} \rho \langle v^2 \rangle$$

$$\rho = \frac{Nm}{V}$$

Integrals:

$$\int_0^{+\infty} e^{-ax^2} dx = \frac{1}{2} \sqrt{\frac{\pi}{a}}$$

$$\int_0^{+\infty} xe^{-ax^2} dx = \frac{1}{2a}$$

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

$$\int_0^{+\infty} x^3 e^{-ax^2} dx = \frac{1}{2a^2}$$

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

$$\int_0^{+\infty} \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$$

$$\Delta E_{int} = Q + W$$

$$pV = nRT$$

$$\Delta S = \int \frac{dQ}{T}$$

Change	$\Delta E_{int}$	W	Q	$\Delta S$
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	$nC_v \Delta T$	$\frac{1}{\gamma - 1} (p_f V_f - p_i V_i)$	0	0

$$pV^\gamma = const.$$

$$\gamma = \frac{C_p}{C_v}$$

$$C_p - C_v = R$$

$$\epsilon_{CRV} = \frac{W}{Q} = \left| \frac{Q_H - Q_L}{Q_H} \right| = 1 - \frac{T_C}{T_H}$$

$$COP = \frac{\text{what we want}}{\text{what we pay for it}}$$

$$\Delta L = \alpha L \Delta T$$

$$\Delta S = \beta \Delta T$$

$$\Delta V = \gamma V \Delta T$$

$$P = e \sigma A T^4; \quad \sigma = 5.67 \times 10^{-8} \text{ W}/(\text{K}^4 \text{ m}^2)$$

$$P = kA \left| \frac{dT}{dx} \right|$$

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

$$c(\text{water}) = 4186 \text{ J}/(\text{kg C}); \quad c(\text{ice}) = 2090 \text{ J}/(\text{kg C}); \quad c(\text{steam}) = 2010 \text{ J}/(\text{kg C})$$

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