HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF ENGINEERING PHYSICS

ADVANCED PROGRAMS - PHYSICS FINAL EXAM - SPRING 2020

Time: **90 minutes** Class code: **114767** Subject code: **PH1110**

Name:..DOB:....................ID:.....................

For Examiner's Use

Question:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	Total
Points:	4	8	7	5	5	5	10	11	55
Score:									

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1. The position vector of an ion is initially $\vec{\mathbf{r}}_0 = 5.0\,\hat{\mathbf{x}} - 6.0\,\hat{\mathbf{y}} + 2.0\,\hat{\mathbf{z}}$, and is $\vec{\mathbf{r}} = -2.0\,\hat{\mathbf{x}} + 8.0\,\hat{\mathbf{y}} - 2.0\,\hat{\mathbf{z}}$ two minutes later, all in meters. **4 p**

(**a**) In unit-vector notation, find the average velocity of the ion during the two minutes. [2]

$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}} - \vec{\mathbf{r}}_0 = -7.0\,\hat{\mathbf{x}} + 14\,\hat{\mathbf{y}} - 4.0\,\hat{\mathbf{z}}$ .... [C1]

$\vec{\mathbf{v}} = \Delta\vec{\mathbf{r}}/\Delta t = -0.058\,\hat{\mathbf{x}} + 0.12\,\hat{\mathbf{y}} - 0.033\,\hat{\mathbf{z}}$ .... [A1]

(**b**) State and explain whether or not it is possible to determine the average speed of the ion with the given information. [2]

no, it is not possible .... [B1]

because it is not possible to determine the distance moved .... [B1]

2. You throw a ball toward a wall at speed $22.0\,\mathrm{m\,s^{-1}}$ and at angle of $\theta_0 = 35°$ above the horizontal, as shown in **Fig. 2.1**. The wall is distance $d = 25.0\,\mathrm{m}$ from the release point of the ball. **8 p**

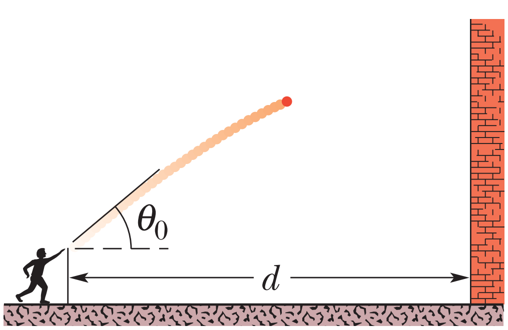

Fig. 2.1

(**a**) How far above the release point does the ball hit the wall? [3]

$x = (22.0\cos 35°)t = 18.02t$

$y = (22.0\sin 35°)t - gt^2/2 = 12.62t - 4.90t^2$ .... [C1]

the ball hits the wall when $x = d$

$18.02t = 25.0 \quad\rightarrow\quad t = 1.387\,\mathrm{s}$ .... [C1]

the ball hits the wall at heigh

$h = 12.62 \times 1.387 - 4.90 \times 1.387^2 = 8.08\,\mathrm{m}$ .... [A1] (**b**) Determine, for the velocity of the ball as it hits the wall,

i. the horizontal component, [1]

$v_x = 18.0\,\mathrm{m\,s^{-1}}$ .... [A1]

ii. the vertical component. [2]

$v_y = \dot{y} = 12.62 - 9.81t$ .... [C1]

$v_y = 12.62 - 9.81 \times 1.387 = -0.986\,\mathrm{m\,s^{-1}}$ .... [A1]

(**c**) State and explain if the ball has passed the highest point on its trajectory when it hits the wall. [2]

yes, it has .... [B1]

since $v_y < 0$ at that instant .... [B1]

3. For a particle moving around a point, suppose that the net torque acting on the particle and the angular momentum of the particle about the point are $\vec{\boldsymbol{\tau}}$ and $\vec{\mathbf{L}}$, respectively. **7 p**

(**a**) State the formulae for the definitions of $\vec{\boldsymbol{\tau}}$ and $\vec{\mathbf{L}}$. Explain your notations. [4]

$\vec{\boldsymbol{\tau}} = \vec{\mathbf{r}} \times \vec{\mathbf{F}}$ .... [C1]

$\vec{\mathbf{L}} = \vec{\mathbf{r}} \times \vec{\mathbf{p}}$ .... [C1]

$\vec{\mathbf{r}}$ is the position vector and $\vec{\mathbf{p}}$ is the momentum of the particle <u>with respect to the point</u> [C1]

$\vec{\mathbf{F}}$ is the <u>net</u> force acting on the particle .... [A1] (**b**) Use the results in (**a**) to show that [3]

$$\vec{\boldsymbol{\tau}} = \dot{\vec{\mathbf{L}}} \equiv \frac{\mathrm{d}\vec{\mathbf{L}}}{\mathrm{d}t}$$

$\vec{\mathbf{F}} = \dot{\vec{\mathbf{p}}} \quad \rightarrow \quad \vec{\mathbf{r}} \times \vec{\mathbf{F}} = \vec{\mathbf{r}} \times \dot{\vec{\mathbf{p}}}$ .... [C1]

$\frac{\mathrm{d}}{\mathrm{d}t}(\vec{\mathbf{r}} \times \vec{\mathbf{p}}) = \dot{\vec{\mathbf{r}}} \times \vec{\mathbf{p}} + \vec{\mathbf{r}} \times \dot{\vec{\mathbf{p}}} = \vec{\mathbf{v}} \times (m\vec{\mathbf{v}}) + \vec{\mathbf{r}} \times \dot{\vec{\mathbf{p}}} = \vec{\mathbf{r}} \times \dot{\vec{\mathbf{p}}}$ .... [C1]

$\rightarrow \quad \vec{\mathbf{r}} \times \vec{\mathbf{F}} = \frac{\mathrm{d}}{\mathrm{d}t}(\vec{\mathbf{r}} \times \vec{\mathbf{p}}) \quad \rightarrow \quad \vec{\boldsymbol{\tau}} = \dot{\vec{\mathbf{L}}}$ .... [A1]

4. A 75-kg petty thief wants to escape from a third-story jail window. Unfortunately, a makeshift rope made of sheets tied together can support a mass of only 58 kg. **5 p**

(**a**) How might the thief use this 'rope' to escape? [2]

the tension less than his weight → net force downwards .... [B1]

he might escape by accelerating downwards .... [B1]

(**b**) Give a quantitative answer. [2]

$F_{\text{net}} = (75 - 58) \times 9.8 = 167\,\mathrm{N}$ .... [C1]

$a = F_{\text{net}}/m = 167/75 = 2.2\,\mathrm{m\,s^{-2}}$ .... [A1]

(**c**) What is the *inertia* of an object? [1]

the resistance to change in motion .... [B1]

5. A ball of mass 0.440 kg moving east ($+x$ direction) with a speed of $3.80\,\mathrm{m\,s^{-1}}$ collides head-on with a 0.220-kg ball at rest. If the collision is perfectly elastic, what will be the speed and direction of each ball after the collision? [5]

$m_1u_1 = m_1v_1 + m_2v_2$ .... [B1]

$m_1u_1^2/2 = m_1v_1^2/2 + m_2v_2^2/2$ .... [B1]

$v_1 = (m_1 - m_2)u_1/(m_1 + m_2) = (0.440 - 0.220) \times 3.80/(0.440 + 0.220) = 1.27\,\mathrm{m\,s^{-1}}$ .... [B1]

$v_2 = 2m_1u_1/(m_1 + m_2) = 2 \times 0.440 \times 3.80/(0.440 + 0.220) = 5.07\,\mathrm{m\,s^{-1}}$ .... [B1]

both balls move east or both balls move in the $+x$ direction .... [B1]

6. Rain is falling at the rate of $3.5\,\mathrm{cm\,h^{-1}}$ and accumulates in a pan. If the raindrops hit at $10.0\,\mathrm{m\,s^{-1}}$, estimate the force on the bottom of a $1.0\text{-}\mathrm{m^2}$ pan due to the impacting rain which we assume does not rebound. The density of water is $1.00 \times 10^3\,\mathrm{kg\,m^{-3}}$. [5]

$F = \Delta p/\Delta t$ .... [C1]

$F = (\Delta m/\Delta t)v$ .... [C1]

$F = [A(\Delta h/\Delta t)\rho]v$ .... [C1]

$F = 1.0 \times (3.5 \times 10^{-2}/3.6 \times 10^3) \times 1.00 \times 10^3 \times 10.0$ .... [C1]

$F = 9.7(2) \times 10^{-2}\,\mathrm{N}$ .... [A1]

7. In **Fig. 7.1**, block 1 has mass $m_1 = 460\,\text{g}$, block 2 has mass $m_2 = 500\,\text{g}$, and the pulley, which is mounted on a horizontal axle with negligible friction, has radius $R = 5.00\,\text{cm}$. **10 p**

When released from rest, block 2 falls 75.0 cm in 5.00 s without the cord slipping on the pulley.

(**a**) What is the magnitude of the acceleration of the blocks? [5]

Down is taken to be positive .... [B1]

a is the magnitude of the acceleration .... [C1]

$s = ut + at^2/2$ .... [C1]

$75.0 \times 10^{-2} = a \times 5.00^2/2$ .... [C1]

$a = 6.00 \times 10^{-2}\,\text{m}\,\text{s}^{-2}$ .... [A1]

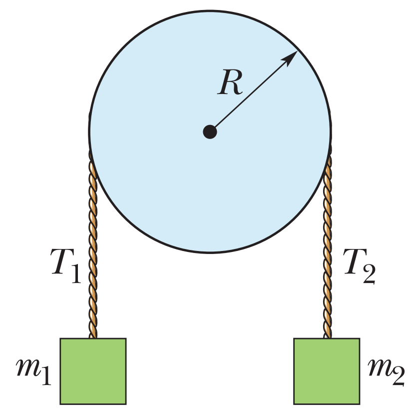

Fig. 7.1

(**b**) Calculate the tensions T_1 and T_2. [2]

$T_1 - m_1 g = m_1 a$ and $m_2 g - T_2 = m_2 a$ .... [C1]

$T_1 = 0.460 \times (9.81 + 6.00 \times 10^{-2}) = 4.54\,\text{N}$

and $T_2 = 0.500 \times (9.81 - 6.00 \times 10^{-2}) = 4.87\,\text{N}$ .... [A1]

(**c**) Determine the rotational inertia of the pulley. [3]

$\vec{\boldsymbol{\tau}}_{\text{net}} = I\vec{\boldsymbol{\beta}}$ or $\tau_{\text{net}} = I\beta$ .... [C1]

$(T_2 - T_1)R = I(a/R) \quad \rightarrow \quad I = (T_2 - T_1)R^2/a$ .... [C1]

$I = (4.87 - 4.54) \times (5.00 \times 10^{-2})^2/6.00 \times 10^{-2} = 13.8 \times 10^{-2}\,\text{kg}\,\text{m}^2$ .... [A1]

8. **11 p**

(**a**) The first law of thermodynamics may be expressed in the form $\Delta U = w + q$.

i. State, for a system, what is meant by: [2]

1. $+q$

energy transfer to the system by heating .... [B1]

2. $+w$.

(external) work done on the system .... [B1]

ii. State what is represented by a negative value of ΔU. [1]

decrease in internal energy .... [B1]

(**b**) An ideal gas, sealed in a container, undergoes the cycle of changes shown in **Fig. 8.1**.

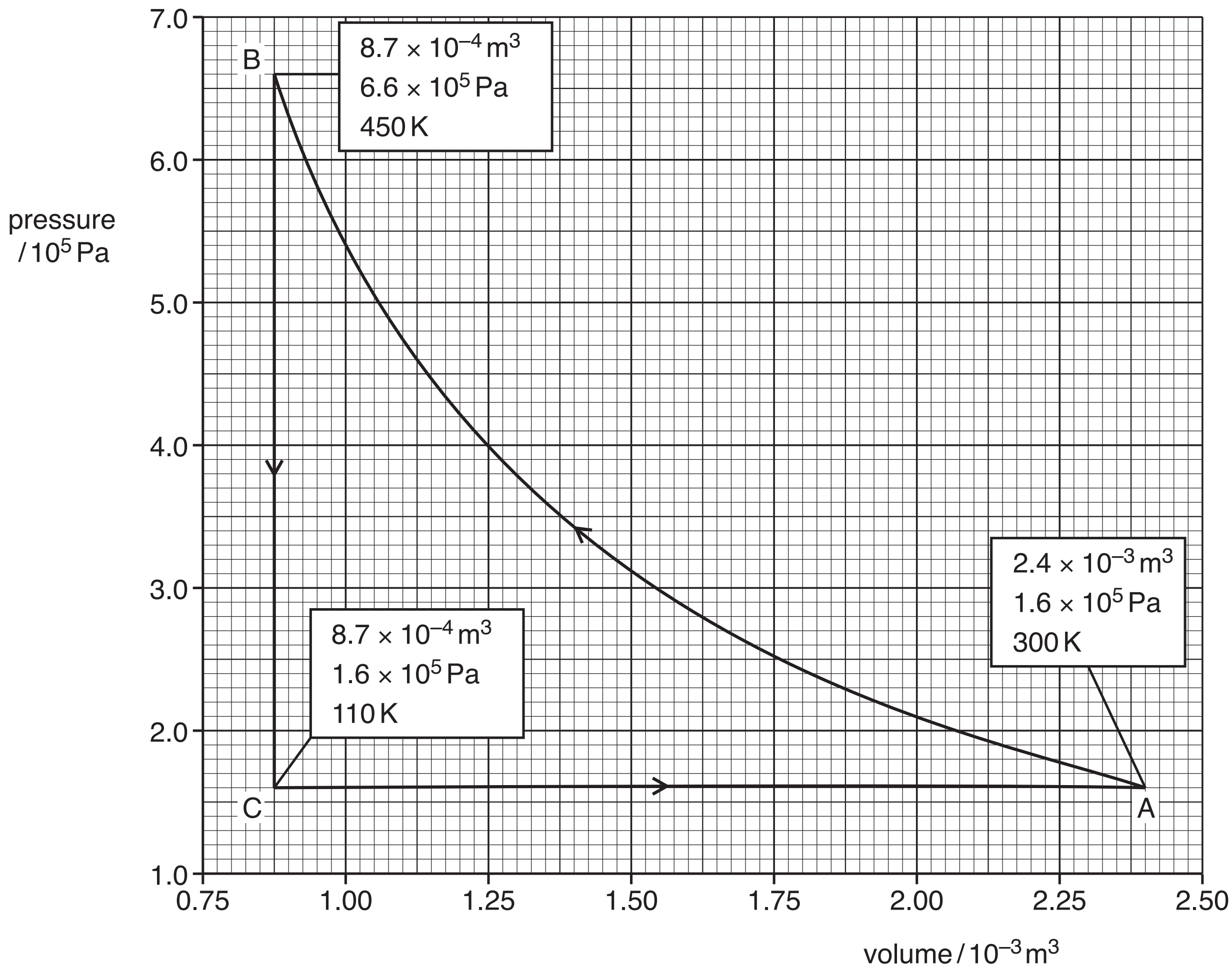

Fig. 8.1

At point A, the gas has volume 2.4×10^{-3} m^3, pressure 1.6×10^5 Pa and temperature 300 K.

The gas is compressed suddenly so that no thermal energy enters or leaves the gas during the compression. The amount of work done is 480 J so that, at point B, the gas has volume $8.7 \times 10^{-4}\,\mathrm{m}^3$, pressure 6.6×10^5 Pa and temperature 450 K.

The gas is now cooled at constant volume so that, between points B and C, 1100 J of thermal energy is transferred. At point C, the gas has pressure 1.6×10^5 Pa and temperature 110 K.

Finally, the gas is returned to point A.

i. State and explain the total change in internal energy of the gas for one complete cycle. [2]

no change (in internal energy) .... [B1]

(because) no change in temperature .... [B1]

ii. Calculate the external work done on the gas during the expansion from C to A. [2]

work done $= p\Delta V = (-)1.6 \times 10^5 \times (2.4 - 0.87) \times 10^{-3}$ ....[C1]

$= (-)240$ J .... [A1]

iii. Complete **Fig. 8.2** for the changes from point A to point B, point B to point C, and point C to point A. [4]

change	$+q$/J	$+w$/J	ΔU/J
A → B	........0..........	.......480.......	.....480.........
B → C	.......-1100.....	........0..........	...-1100........
C → A	.......860........	.....-240........	.....620.........

Fig. 8.2

first row all correct (0, 480, 480) .... [A1]

second row all correct (-1100, 0, -1100) .... [A1]

final column of third row calculated correctly from the two values above it,

so that the final column adds up to 0 .... [A1]

second column in final row correct, with correct negative sign **and** first column in final row calculated correctly so that it adds to the second column to give the third column [A1]

Director of the Department of Theoretical Physics **Leturer**

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