HUST - ADVANCED PROGRAMS - PHYSICS PH1110 MIDTERM - SPRING 2020

This exam contains 4 pages, 5 questions for the total of 36 points. On average, you will have 1.25 minutes for each point. Give your answers in the spaces provided on the question sheets.

Name:.. Date of birth:..

Class:.. Student ID:..

For Examiner's Use

Question:	**1**	**2**	**3**	**4**	**5**	Total
Points:	6	4	10	7	9	36
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. A boy whirls a stone in a horizontal circle at height 1.5 m above level ground with a centripetal acceleration of $150\,\mathrm{m\,s^{-2}}$. [6]

The string breaks, and the stone flies off horizontally and strikes the ground after traveling a horizontal distance of 8.0 m.

What is the radius of the orbit during the circular motion of the stone?

the initial speed u of the projectile motion is the speed of the UCM .... [B1]

for the projectile motion, choose the y axis downwards

$x = ut, \quad y = gt^2/2 \quad \rightarrow \quad y = gx^2/2u^2$ .... [C1]

$x = R$ (range) when $y = h \quad \rightarrow \quad u = \sqrt{gR^2/2h}$ .... [C1]

$u = \sqrt{9.8 \times 8.0^2/(2 \times 1.5)} = 14.46\,\mathrm{m\,s^{-1}}$ .... [C1]

for the UCM

$r = u^2/a \quad (r = \text{radius})$ .... [C1]

$r = 14.46^2/150 = 1.4\,(1.39)\,\mathrm{m\,s^{-2}}$ .... [A1]

2. **Fig. 2.1** depicts the motion of a particle moving along an x axis with a constant acceleration. The figure's vertical scaling is set by $x_s = 6.0$ m. Determine the initial speed of the particle. [4]

standard form of equation for UALM:

$x = x_0 + ut + at^2/2$ .... [C1]

the graph goes through three points:

$(0.0, -2.0), \quad (1.0, 0.0), \quad$ and $\quad (2.0, 6.0)$ .... [C1]

$-2.0 = x_0$

$0.0 = x_0 + 1.0u + 0.5a$

$6.0 = x_0 + 2.0u + 2.0a$ .... [C1]

$u = 0.00\,\mathrm{m\,s^{-2}}$ .... [A1]

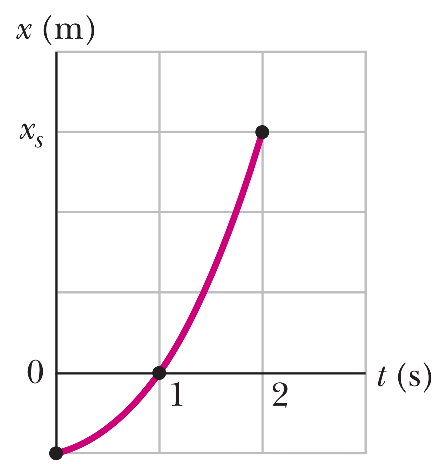

Fig. 2.1

3. In **Fig. 3.1**, a constant horizontal force $\vec{\mathbf{F}}_a$ is applied to block A, which pushes against block B with a 20.0 N force directed horizontally to the right. In **Fig. 3.2**, the same force is applied to block B; now block A pushes on block B with a 10.0 N force directed horizontally to the left. **10 p**

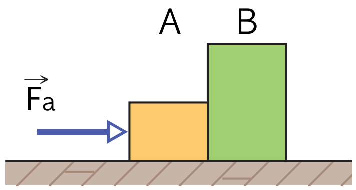

Fig. 3.1

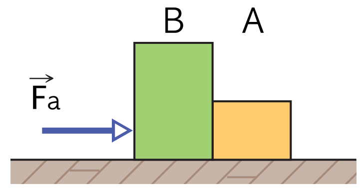

Fig. 3.2

The blocks have a combined mass of 12.0 kg. Friction is negligible.

(**a**) Determine the magnitude of the acceleration of the system in **Fig. 3.1**. [6]

In both cases: $F_a = (m_A + m_B)a = (12.0\,\text{kg}) \times a$ .... [C1]

In **Fig. 3.1**: $20.0\,\text{N} = m_B a$ .... [C1]

In **Fig. 3.2**: (by Newton's third law,) block B pushes block A with a 10.0 N force ..... [B1]

$10.0\,\text{N} = m_A a$ .... [C1]

$20.0 + 10.0 = (m_A + m_B)a \quad \rightarrow \quad 30.0 = 12.0a$ .... [C1]

$a = 30.0/12.0 = 2.5\,\text{m}\,\text{s}^{-2}$ .... [A1]

(**b**) Calculate the magnitude of the force $\vec{\mathbf{F}}_a$. [1]

$F_a = 12.0 \times 2.5 = 30.0\,\text{N}$ .... [A1]

(**c**) **i**. Define *momentum* of an object. [1]

product of mass and velocity .... [B1]

ii. State the *first theorem about momentum* (second form of Newton's second law of motion). [2]

The net force acting on a particle .... [B1]

is equal to the rate of change of the particle's momentum .... [B1]

4. **7 p**

(**a**) **i**. State what is meant by *gravitational potential* at a point. [2]

work done per unit mass .... [B1]

work done moving mass from infinity (to the point) .... [B1]

ii. Suggest why, for small changes in height near the Earth's surface, gravitational potential is approximately constant. [2]

(near Earth's surface change in) height much less than radius .... [B1]

potential inversely proportional to radius and
radius approximately constant (so potential approximately constant) .... [B1]

(**b**) The Moon may be considered to be a uniform sphere with a diameter of 3.5×10^3 km and a mass of 7.4×10^{22} kg. [3]

A meteor strikes the Moon and, during the collision, a rock is sent off from the surface of the Moon with an initial speed v.

Assuming that the Moon is isolated in space, determine the minimum speed of the rock such that it does not return to the Moon's surface. Explain your working.

initial kinetic energy = (−) potential energy (at surface) **or** $mv^2/2 = GMm/r$ ...... [B1]

$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22})/(0.5 \times 3.5 \times 10^6)$ .... [C1]

$v = 2.4 \times 10^3\,\mathrm{m\,s^{-1}}$ .... [A1]

5. Early test flights for the space shuttle used a "glider" (mass of 980 kg including pilot). **9 p**

After a horizontal launch at $480\,\mathrm{km\,h^{-1}}$ at a height of 3500 m, the glider eventually landed at a speed of $210\,\mathrm{km\,h^{-1}}$.

(**a**) What would its landing speed have been in the absence of air resistance? [4]

mechanical energy is conserved / $E_{\mathrm{ki}} + E_{\mathrm{pi}} = E'_{\mathrm{kf}}$ .... [C1]

$mv_\mathrm{i}^2/2 + mgh = mv_\mathrm{f}'^2/2$ (thus, $v'_\mathrm{f} = \sqrt{v_\mathrm{i}^2 + 2gh}$) .... [C1]

$v'_\mathrm{f} = \sqrt{(480/3.6)^2 + 2 \times 9.81 \times 3500}$ .... [C1]

$v'_\mathrm{f} = 290\,(294)\,\mathrm{m\,s^{-1}}$ **or** $v'_\mathrm{f} = 1100\,(1060)\,\mathrm{km\,h^{-1}}$ .... [A1]

(**b**) What was the average force of air resistance exerted on it if it came in at a constant glide angle of 12° to the Earth's surface? [5]

work done by air resistance is equal to the difference in kinetic energy

or work done by air resistance is equal to the change in mechanical energy .... [B1]

$W = mv_\mathrm{f}^2/2 - mv_\mathrm{f}'^2/2$ **or** $W = mv_\mathrm{f}^2/2 - (mv_\mathrm{i}^2/2 + mgh)$ .... [C1]

$W = F_\mathrm{r} d = F_\mathrm{r} h/\sin\theta \quad \rightarrow \quad F_\mathrm{r} = m(v_\mathrm{f}^2 - mv_\mathrm{f}'^2)\sin\theta/2h$ .... [C1]

$F_\mathrm{r} = 980 \times [(210/3.6)^2 - 294^2] \times \sin 12°/(2 \times 3500)$ .... [C1]

$F_\mathrm{r} = (-)2400\,(2420)\,\mathrm{N}$ .... [A1]