**Mid-Semester Test**

Name : ______________________________ Adm. No. : _______________

Class : ________________________ Class S/N : ______________

Date : ________________________ Time allowed : 1 hour

Maximum mark : 100

**Instructions**

Answer all 4 questions. Take g = 9.80 m/s$^2$.

This question paper consists of 3 printed pages including 1 page of formulae.

You are reminded that cheating during this test is a serious offence.

All working in support of your answer must be shown. Answers must be to appropriate significant figures.

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1. a) In the below equation, the SI units of $x$ and $x_0$ are in metres, $t$ and $t_0$ are in seconds, $v_0$ is m/s and $a$ is m/s$^2$. Using the dimensional analysis show whether the equation is homogenous or not.

$$x = x_0 + v_0(t - t_0) + \frac{1}{2}a(t - t_0)^2$$

b) A particle is under a constant force **F** = (-2**i** + 4**j** + **k**) as it moves from a point (5, 1, 2) to another point (-2, 3, 4). Find the work done on the particle.

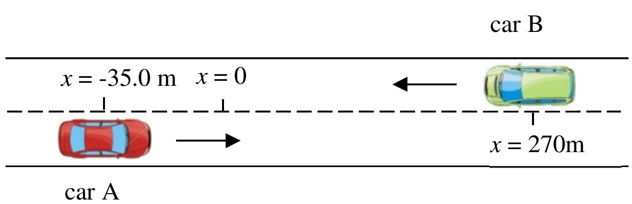
c) What is the angle between the displacement and force vectors in 1(b)?

(25 marks)

2. In the figure below, car A and car B, moves towards each other in adjacent lanes and parallel to an $x$ axis. At time $t$ = 0, car A is at $x$ = -35.0 m and accelerates uniformly from rest at 2 m/s$^2$ while car B is at $x$ = 270 m moving at a constant speed of 20.0 m/s.

a) When do the cars meet?
b) Where do the cars meet?
c) What is the speed of car A when it crosses car B?
d) Sketch the displacement-time plots of the two cars on the same graph.

(25 marks)



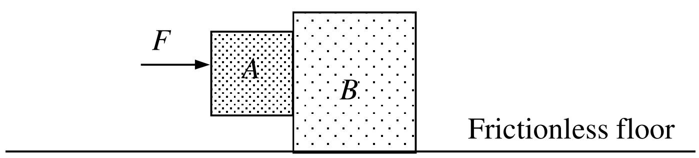
3. The position vector of a particle of mass 2.0 kg moving on the *x*-*y* plane is $\vec{r} = 2t\ \hat{i} + 2\sin(\pi t/4)\ \hat{j}$, with $\vec{r}$ in metres and *t* in seconds. Calculate in component form the

a) particle's average velocity during the first second of its journey.
b) particle's velocity at $t = 1.0$ s.
c) force acting on the particle at $t = 1.0$ s.

(25 marks)

4. The two blocks ($A = 16$ kg and $B = 88$ kg) in the figure below are not attached to each other. The coefficient of static friction between the two blocks is $\mu_s = 0.33$, but the surface beneath the larger block is frictionless.

a) Draw the free-body diagram for blocks *A* and *B* if a force *F* acts on *A* as shown in the figure.
b) What is the magnitude of the minimum force *F* required to keep block *A* from slipping down block *B*?
c) If *F* acts on block *B* instead of block *A*, what is the magnitude of *F* so that block *A* does not fall off block *B*?




(25 marks)

***** End of Paper *****

# Formula sheet

Name: ________________________ Admin. No.: ________________ Seat No.: ________

## Kinematics

$$v_x = v_{0x} + a_x t$$
$$v_x{}^2 = v_{0x}{}^2 + 2a_x(x - x_0)$$
$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$
$$\vec{v} = \frac{d\vec{r}}{dt}, \quad \vec{a} = \frac{d\vec{v}}{dt}$$
$$y = (\tan\theta)x - \left(\frac{g}{2v^2\cos^2\theta}\right)x^2$$
$$R = \frac{v^2 \sin 2\theta}{g}$$

## Dynamics

$$\vec{F} = m\frac{d\vec{v}}{dt} = m\vec{a},\ F = \mu N$$
$$a = \frac{dv}{dt},\ a = \frac{v^2}{r}, F = m\frac{v^2}{r}$$
$$\vec{J} = \int \vec{F}dt = \Delta\vec{p}$$
$$W = \int \vec{F}.\vec{dr},\ W_{net} = K_f - K_i$$
$$KE = \frac{1}{2}mv^2,\ PE = mgh$$
$$P = \frac{W}{t}, \quad P = \frac{dW}{dt}$$

## Linear momentum

$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

## Static electricity

$$F = k\frac{q_1 q_2}{r^2},\ k = \frac{1}{4\pi\varepsilon_o}$$
$$F = qE$$
$$V = k\frac{q}{r},\ U = qV$$
$$\Phi_E = \oint \vec{E}.d\vec{A} = \frac{q}{\varepsilon_o}$$
$$V = Ed,\ W = qV,\ E = \frac{kq}{r^2}$$

## Current electricity

$$Q = It \qquad V = IR$$
$$P = VI = I^2R = \frac{V^2}{R}$$

## Magnetism & electromagnetism

$$\vec{F} = q\vec{v}\times\vec{B} \qquad \vec{F} = i\vec{L}\times\vec{B}$$
$$e.m.f. = -N\frac{d\Phi_B}{dt} \qquad \Phi_B = BA$$

## Thermodynamics

$$\Delta U = Q - W$$
$$W = \int p\,dV$$
$Q_V = nC_V\Delta T$ const vol

$Q_p = nC_p\Delta T$ const pressure

$$Q = mC\Delta T$$
$$Q = mL$$

## Ideal Gas

$$pV = nRT$$
$pV^\gamma = c$ (adiabatic)

$$\gamma = \frac{C_p}{C_V},\ C_p - C_v = R$$
$$W = pV\ln\frac{V_2}{V_1} = nRT\ln\frac{V_2}{V_1}$$
$$W = \frac{1}{\gamma - 1}(p_1V_1 - p_2V_2)$$

## Rotational Motion

$$\omega = \frac{d\theta}{dt}, \quad \alpha = \frac{d\omega}{dt}$$
$$\omega = \omega_0 + \alpha t$$
$$\omega^2 = \omega_0{}^2 + 2\alpha(\theta - \theta_0)$$
$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$
$$I = \sum_i^n m_i r_i^2,\ I = \int r^2 dm,\ K = \frac{1}{2}I\omega^2$$

## SHM & waves

$$T = \frac{1}{f} \quad v = f\lambda \quad \omega = 2\pi f$$
$$\omega = \frac{2\pi}{T} \quad k = \frac{2\pi}{\lambda}$$
$$\omega = \sqrt{k/m} \quad \omega = \sqrt{g/L}$$
$$x = A\cos(\omega t + \phi)$$
$$x = A\sin(\omega t + \phi)$$
$$y(x,t) = A\cos(\omega t \pm kx)$$
$$y(x,t) = A\sin(\omega t \pm kx)$$
$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

## Circuits

$R = R_1 + R_2 + R_3 + \ldots$ series

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$ parallel

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$ series

$C = C_1 + C_2 + C_3 + \ldots$ parallel

$$Q = CV \qquad U = \frac{1}{2}CV^2$$

## Constants

Charge on electron
$e = -1.60\times10^{-19}$ C

Coulomb's constant
$k = 9\times10^{9}$ N m$^2$ C$^{-2}$

Ideal gas constant
$R = 8.314$ J mol$^{-1}$ K$^{-1}$

Mass of proton
$m_p = 1.67\times10^{-27}$ kg

Mass of electron
$m_e = 9.11\times10^{-31}$ kg

Permeability of free space
$\mu_o = 4\pi\times10^{-7}$ N A$^{-2}$

Permittivity of free space
$\varepsilon_o = 8.85\times10^{-12}$ C$^2$ N$^{-1}$ m$^{-2}$

Speed of light in vacuum
$c = 3.00\times10^{8}$ m s$^{-1}$