AP® Physics B
2008 Free-Response Questions
Form B

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TABLE OF INFORMATION FOR 2008 and 2009

CONSTANTS AND CONVERSION FACTORS

Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, $1 \text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol^{-1}	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg•s^2
Universal gas constant, $R = 8.31$ J/(mol•K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27}$ kg $= 931$ MeV/c^2
Planck's constant,	$h = 6.63 \times 10^{-34}$ J•s $= 4.14 \times 10^{-15}$ eV•s
	$hc = 1.99 \times 10^{-25}$ J•m $= 1.24 \times 10^{3}$ eV•nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/N•m^2
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ N•m^2/C^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T•m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}$ (T•m)/A
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^{5}$ N/m^2 $= 1.0 \times 10^{5}$ Pa

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron-volt,	eV
	kelvin,	K	joule,	J	henry,	H		

PREFIXES

Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

IV. For mechanics and thermodynamics equations, *W* represents the work done on a system.

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2008 and 2009

NEWTONIAN MECHANICS

$$\upsilon = \upsilon_0 + at$$

$$x = x_0 + \upsilon_0 t + \frac{1}{2}at^2$$

$$\upsilon^2 = \upsilon_0^2 + 2a(x - x_0)$$

$$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$$

$$F_{fric} \le \mu N$$

$$a_c = \frac{\upsilon^2}{r}$$

$$\tau = rF\sin\theta$$

$$\mathbf{p} = m\mathbf{v}$$

$$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$$

$$K = \frac{1}{2}m\upsilon^2$$

$$\Delta U_g = mgh$$

$$W = F\Delta r\cos\theta$$

$$P_{avg} = \frac{W}{\Delta t}$$

$$P = F\upsilon\cos\theta$$

$$\mathbf{F}_s = -k\mathbf{x}$$

$$U_s = \frac{1}{2}kx^2$$

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T = \frac{1}{f}$$

$$F_G = -\frac{Gm_1m_2}{r^2}$$

$$U_G = -\frac{Gm_1m_2}{r}$$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
T = period
t = time
U = potential energy
υ = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

$$\mathbf{E} = \frac{\mathbf{F}}{q}$$

$$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$$

$$E_{avg} = -\frac{V}{d}$$

$$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$$

$$C = \frac{Q}{V}$$

$$C = \frac{\epsilon_0 A}{d}$$

$$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$$

$$I_{avg} = \frac{\Delta Q}{\Delta t}$$

$$R = \frac{\rho\ell}{A}$$

$$V = IR$$

$$P = IV$$

$$C_p = \sum_i C_i$$

$$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$$

$$R_s = \sum_i R_i$$

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

$$F_B = q\upsilon B\sin\theta$$

$$F_B = BI\ell\sin\theta$$

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

$$\phi_m = BA\cos\theta$$

$$\mathcal{E}_{avg} = -\frac{\Delta\phi_m}{\Delta t}$$

$$\mathcal{E} = B\ell\upsilon$$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
υ = velocity or speed
ρ = resistivity
θ = angle
ϕ_m = magnetic flux

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2008 and 2009

FLUID MECHANICS AND THERMAL PHYSICS

$P = P_0 + \rho g h$

$F_{buoy} = \rho V g$

$A_1 \upsilon_1 = A_2 \upsilon_2$

$P + \rho g y + \frac{1}{2}\rho \upsilon^2 = \text{const.}$

$\Delta \ell = \alpha \ell_0 \Delta T$

$H = \frac{kA\,\Delta T}{L}$

$P = \frac{F}{A}$

$PV = nRT = Nk_B T$

$K_{avg} = \frac{3}{2}k_B T$

$\upsilon_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$

$W = -P\Delta V$

$\Delta U = Q + W$

$e = \left|\frac{W}{Q_H}\right|$

$e_c = \frac{T_H - T_C}{T_H}$

A = area
e = efficiency
F = force
h = depth
H = rate of heat transfer
k = thermal conductivity
K_{avg} = average molecular kinetic energy
ℓ = length
L = thickness
M = molar mass
n = number of moles
N = number of molecules
P = pressure
Q = heat transferred to a system
T = temperature
U = internal energy
V = volume
υ = velocity or speed
υ_{rms} = root-mean-square velocity
W = work done on a system
y = height
α = coefficient of linear expansion
μ = mass of molecule
ρ = density

ATOMIC AND NUCLEAR PHYSICS

$E = hf = pc$

$K_{\max} = hf - \phi$

$\lambda = \frac{h}{p}$

$\Delta E = (\Delta m)c^2$

E = energy
f = frequency
K = kinetic energy
m = mass
p = momentum
λ = wavelength
ϕ = work function

WAVES AND OPTICS

$\upsilon = f\lambda$

$n = \frac{c}{\upsilon}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin\theta_c = \frac{n_2}{n_1}$

$\frac{1}{s_i} + \frac{1}{s_0} = \frac{1}{f}$

$M = \frac{h_i}{h_0} = -\frac{s_i}{s_0}$

$f = \frac{R}{2}$

$d\sin\theta = m\lambda$

$x_m \sim \frac{m\lambda L}{d}$

d = separation
f = frequency or focal length
h = height
L = distance
M = magnification
m = an integer
n = index of refraction
R = radius of curvature
s = distance
υ = speed
x = position
λ = wavelength
θ = angle

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2}bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

Parallelepiped
$V = \ell w h$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r\ell + 2\pi r^2$

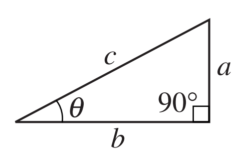
Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

Right Triangle
$a^2 + b^2 = c^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering Questions 1 and 4-7 and about 17 minutes for answering each of Questions 2 and 3. The parts within a question may not have equal weight. Show all your work in the goldenrod booklet in the spaces provided after each part, NOT in this lavender insert.

1. (10 points)

A 70 kg woman and her 35 kg son are standing at rest on an ice rink, as shown above. They push against each other for a time of 0.60 s, causing them to glide apart. The speed of the woman immediately after they separate is 0.55 m/s . Assume that during the push, friction is negligible compared with the forces the people exert on each other.

(a) Calculate the initial speed of the son after the push.

(b) Calculate the magnitude of the average force exerted on the son by the mother during the push.

(c) How do the magnitude and direction of the average force exerted on the mother by the son during the push compare with those of the average force exerted on the son by the mother? Justify your answer.

(d) After the initial push, the friction that the ice exerts cannot be considered negligible, and the mother comes to rest after moving a distance of 7.0 m across the ice. If their coefficients of friction are the same, how far does the son move after the push?

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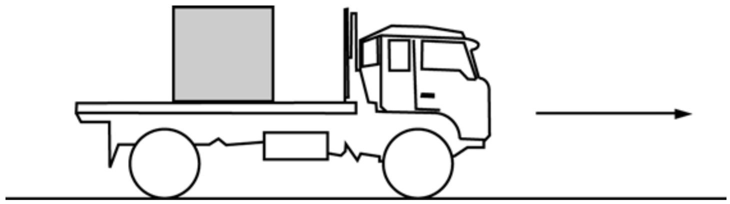
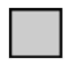


2. (15 points)

A 4700 kg truck carrying a 900 kg crate is traveling at 25 m/s to the right along a straight, level highway, as shown above. The truck driver then applies the brakes, and as it slows down, the truck travels 55 m in the next 3.0 s. The crate does not slide on the back of the truck.

(a) Calculate the magnitude of the acceleration of the truck, assuming it is constant.

(b) On the diagram below, draw and label all the forces acting on the crate during braking.



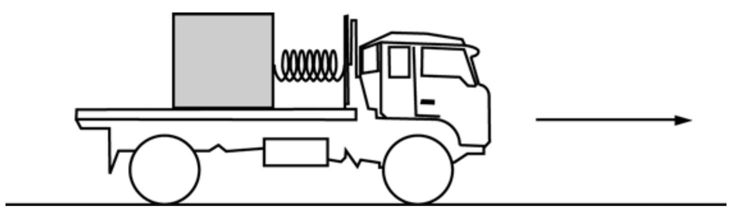
(c)

i. Calculate the minimum coefficient of friction between the crate and truck that prevents the crate from sliding.

ii. Indicate whether this friction is static or kinetic.

____ Static   ____Kinetic

Now assume the bed of the truck is frictionless, but there is a spring of spring constant 9200 N/m attaching the crate to the truck, as shown below. The truck is initially at rest.

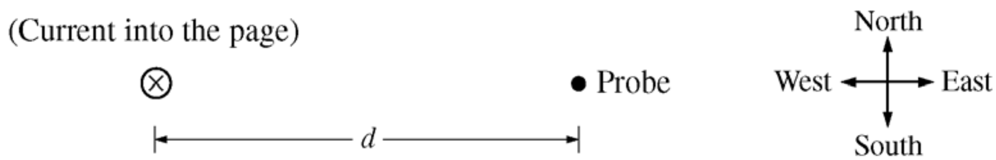


(d) If the truck and crate have the same acceleration, calculate the extension of the spring as the truck accelerates from rest to 25 m/s in 10 s.

(e) At some later time, the truck is moving at a constant speed of 25 m/s and the crate is in equilibrium. Indicate whether the extension of the spring is greater than, less than, or the same as in part (d) when the truck was accelerating.

___ Greater   ___ Less   ___ The same

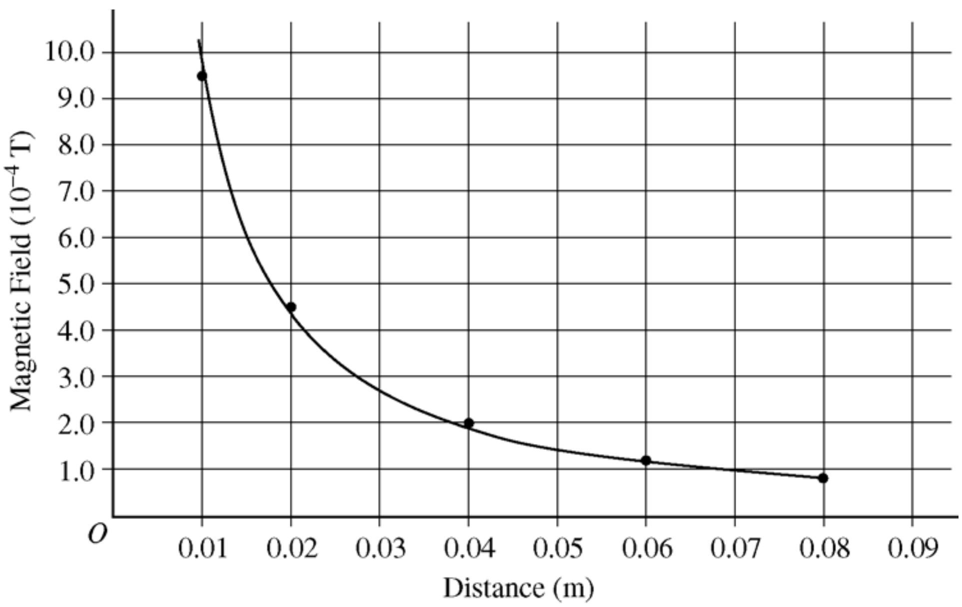
Explain your reasoning.



3. (15 points)

A student is measuring the magnetic field generated by a long, straight wire carrying a constant current. A magnetic field probe is held at various distances *d* from the wire, as shown above, and the magnetic field is measured. The graph below shows the five data points the student measured and a best-fit curve for the data.

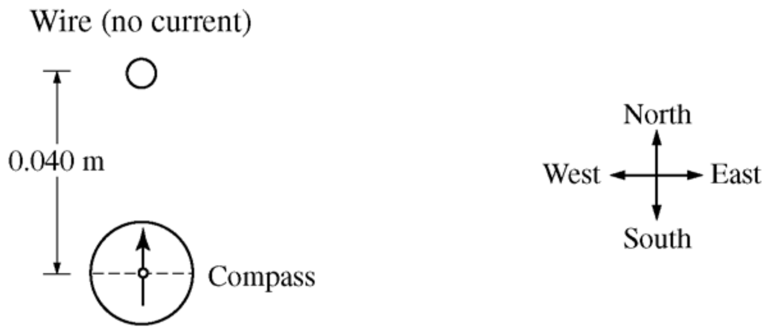
Unfortunately, the student forgot about Earth's magnetic field, which has a value of 5.0×10^{-5} T at this location and is directed north.



(a) On the graph, plot new points for the field due only to the wire.

(b) Calculate the value of the current in the wire.

Another student, who does not have a magnetic field probe, uses a compass and the known value of Earth's magnetic field to determine the magnetic field generated by the wire. With the current turned off, the student places the compass 0.040 m from the wire, and the compass points directly toward the wire as shown below. The student then turns on a 35 A current directed into the page.



Note: Figure not drawn to scale.

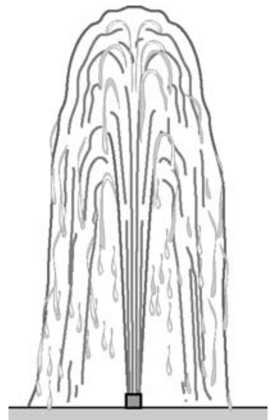
(c) On the compass, sketch the general direction the needle points after the current is established.

(d) Calculate how many degrees the compass needle rotates from its initial position pointing directly north.

The wire is part of a circuit containing a power source with an emf of 120 V and negligible internal resistance.

(e) Calculate the total resistance of the circuit.

(f) Calculate the rate at which energy is dissipated in the circuit.



4. (10 points)

A fountain with an opening of radius 0.015 m shoots a stream of water vertically from ground level at 6.0 m/s. The density of water is $1000\ \text{kg/m}^3$.

(a) Calculate the volume rate of flow of water.

(b) The fountain is fed by a pipe that at one point has a radius of 0.025 m and is 2.5 m below the fountain's opening. Calculate the absolute pressure in the pipe at this point.

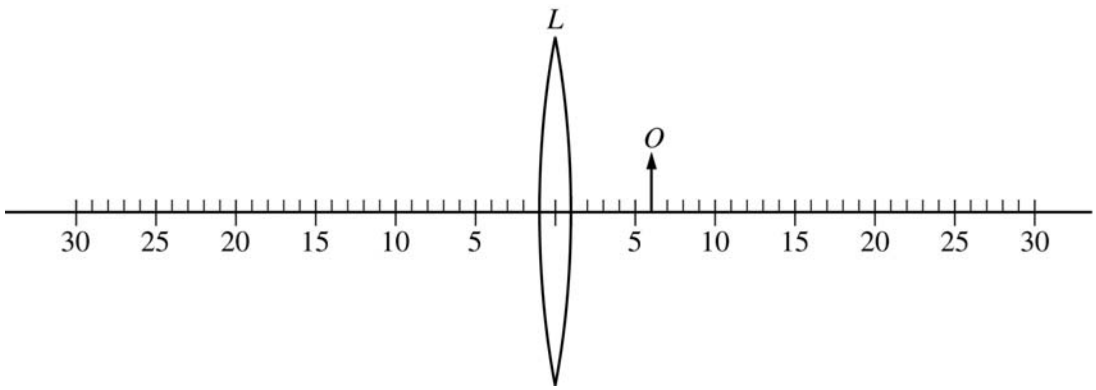
(c) The fountain owner wants to launch the water 4.0 m into the air with the same volume flow rate. A nozzle can be attached to change the size of the opening. Calculate the radius needed on this new nozzle.

GO ON TO THE NEXT PAGE.

5. (10 points)

A thin converging lens *L* of focal length 10.0 cm is used as a simple magnifier to examine an object *O* that is placed 6.0 cm from the lens.

(a) On the figure below, draw a ray diagram showing at least two incident rays and the position and size of the image formed.



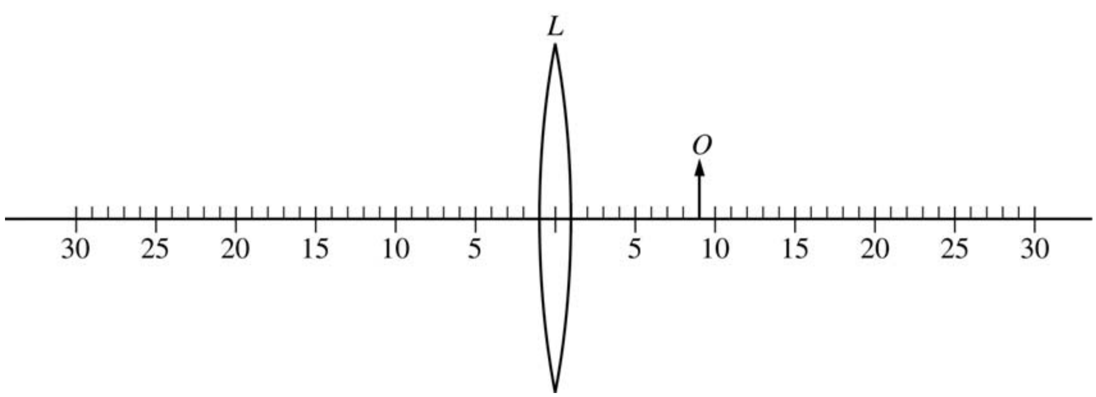
(b)

i. Indicate whether the image is real or virtual.

____ Real ____ Virtual

ii. Justify your answer.

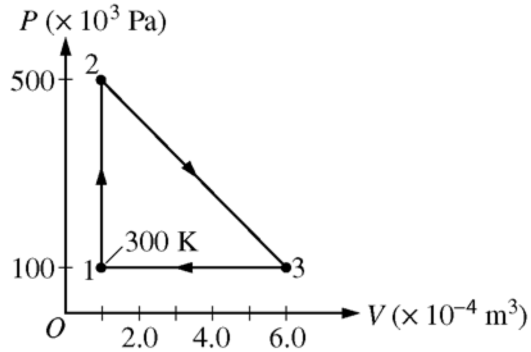
(c) Calculate the distance of the image from the center of the lens. (Do NOT simply measure your ray diagram.)



(d) The object is now moved 3.0 cm to the right, as shown above. How does the height of the new image compare with that of the previous image?

____ It is larger. ____ It is smaller. ____ It is the same size.

Justify your answer.



6. (10 points)

A 0.0040 mol sample of a monatomic gas is taken through the cycle shown above. The temperature T_1 of state 1 is 300 K.

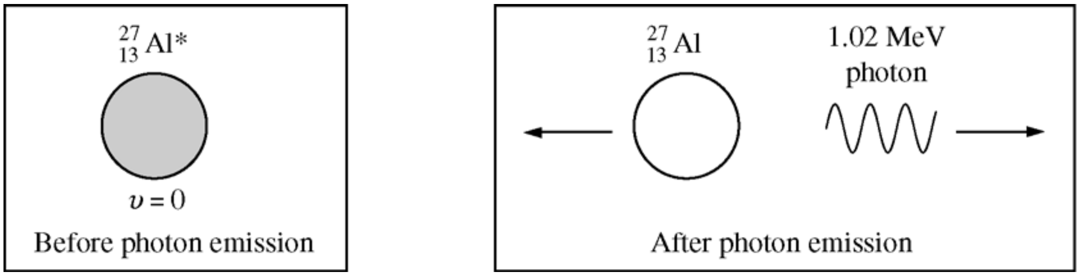
(a) Calculate T_2 and T_3.

(b) Calculate the amount of work done on the gas in one cycle.

(c) Is the net work done on the gas in one complete cycle positive, negative, or zero?

____ Positive ____ Negative ____ Zero

(d) Calculate the heat added to the gas during process $1 \rightarrow 2$.



7. (10 points)

Following a nuclear reaction, a nucleus of aluminum is at rest in an excited state represented by $^{27}_{13}\text{Al}^*$, as shown above left. The excited nucleus returns to the ground state $^{27}_{13}\text{Al}$ by emitting a gamma ray photon of energy 1.02 MeV, as shown above right. The aluminum nucleus in the ground state has a mass of 4.48×10^{-26} kg. Assume nonrelativistic equations apply to the motion of the nucleus.

(a) Calculate the wavelength of the emitted photon in meters.

(b) Calculate the momentum of the emitted photon in $\text{kg}\bullet\text{m/s}$.

(c) Calculate the speed of the recoiling nucleus in m/s.

(d) Calculate the kinetic energy of the recoiling nucleus in joules.

END OF EXAM